AQA Physics (Combined Science) Unit 6.1: Energy

Required Practical

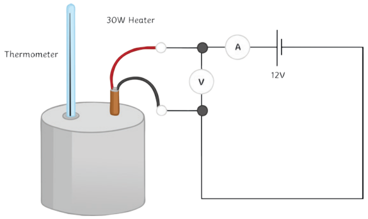
Investigating Specific Heat Capacity

independent variable – material

dependent variable – specific heat capacity

control variables – insulating layer, initial temperature, time taken

$\Delta E = m \times c \times \Delta\theta$



Method:

1. Using the balance, measure and record the mass of the copper block in kg.
2. Wrap the insulation around the block.
3. Put the heater into the large hole in the block and the block onto the heatproof mat.
4. Connect the power pack and ammeter in series and the voltmeter across the power pack.
5. Using the pipette, put a drop of water into the small hole.
6. Put the thermometer into the small hole and measure the temperature.
7. Switch the power pack to 12V and turn it on.
8. Read and record the voltmeter and ammeter readings – during the experiment, they shouldn't change.
9. Turn on the stop clock and record the temperature every minute for 10 minutes.
10. Record the results in the table.
11. Calculate work done and plot a line graph of work done against temperature.

Equations

$E = \frac{1}{2}mv^2$

$E_p = mgh$

$E_e = \frac{1}{2}ke^2$

$\Delta E = m \times c \times \Delta\theta$

$P = \frac{E}{t}$

$P = \frac{W}{t}$

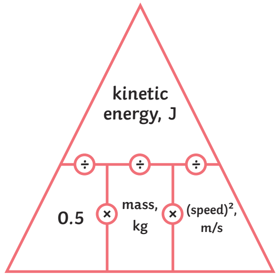
Kinetic and Potential Energy Stores

Movement Energy

kinetic energy = $\frac{1}{2}$ x mass × speed^2

$$E_k = \frac{1}{2}mv^2$$

(J) (kg)(m/s)

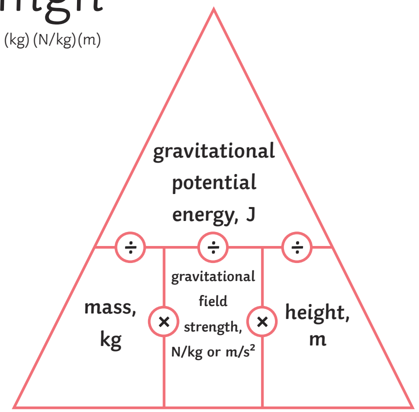


When something is off the ground, it has gravitational potential energy

gravitational potential energy = mass x gravitational field strength x height

$$E_p = mgh$$

(J) (kg) (N/kg)(m)



When an object falls, it loses gravitational potential energy and gains kinetic energy.

Stretching an object will give it elastic potential energy.

elastic potential energy = $\frac{1}{2}$ × spring constant × extension^2

$$E_e = \frac{1}{2}ke^2$$

(J) (N) (m)

Transferring Energy by Heating

Heating a material transfers the energy to its thermal energy store - the temperature increases.

E.g. a kettle: energy is transferred to the thermal energy store of the kettle. Energy is then transferred by heating to the waters thermal energy store. The temperature of the water will then increase.

Some materials need more energy to increase their temperature than others.

change in thermal energy = mass × specific heat capacity × temperature change

$$\Delta E = m \times c \times \Delta\theta$$

(J) (kg) (J/kg˚C) (˚C)

Specific heat capacity is the amount of energy needed to raise the temperature of 1kg of a material by 1˚C.

Energy Stores and Systems

Energy Stores	
kinetic	Moving objects have kinetic energy.
thermal	All objects have thermal energy.
chemical	Anything that can release energy during a chemical reaction.
elastic potential	Things that are stretched.
gravitational potential	Anything that is raised.
electrostatic	Charges that attract or repel.
magnetic	Magnets that attract or repel.
nuclear	The nucleus of an atom releases energy.

Energy can be transferred in the following ways:

mechanically – when work is done;

electrically – when moving charge does work;

heating – when energy is transferred from a hotter object to a colder object.

Conservation of Energy

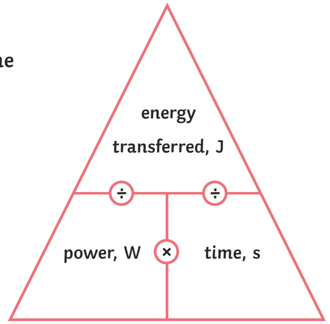
Energy can never be created or destroyed, just transferred from one form to another. Some energy is transferred usefully and some energy gets transferred into the environment. This is mostly wasted energy.

Power

Power is the rate of transfer of energy – the amount of work done in a given time.

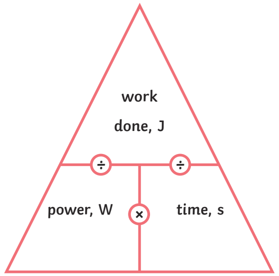
power = energy transferred ÷ time

P (W) = E (J) ÷ t (s)



power = work done ÷ time

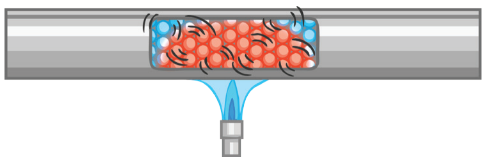
P (W) = W (J) ÷ t (s)



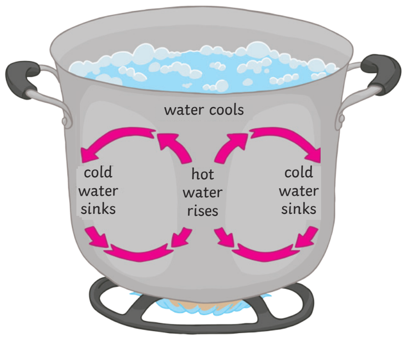
Energy Transfer

Lubrication reduces the amount of friction. When an object moves, there are frictional forces acting. Some energy is lost into the environment. Lubricants, such as oil, can be used to reduce the friction between the surfaces.

Conduction – when a solid is heated, the particles vibrate and collide more, and the energy is transferred.

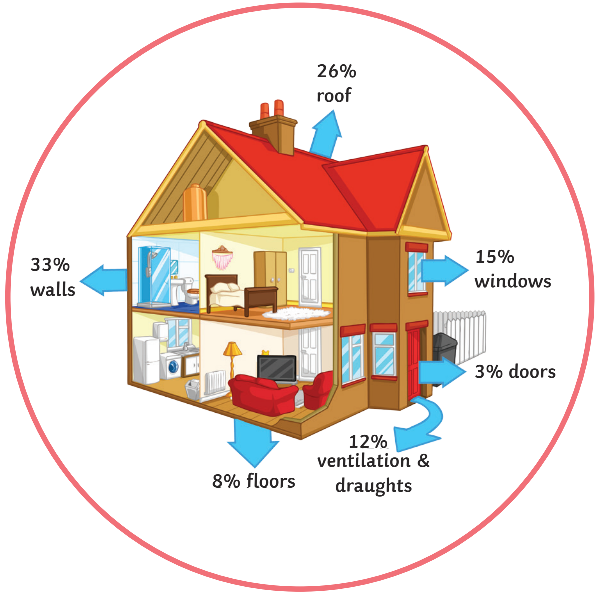


Convection – when a liquid or a gas is heated, the particles move faster. This means the liquid or gas becomes less dense. The denser region will rise above the cooler region. This is a convection current.



Insulation – reduces the amount of heat lost. In your home, you can prevent heat loss in a number of ways:

- thick walls;
- thermal insulation, such as:
- loft insulation (reducing convection);
- cavity walls (reduces conduction and convection);
- double glazing (reduces conduction).

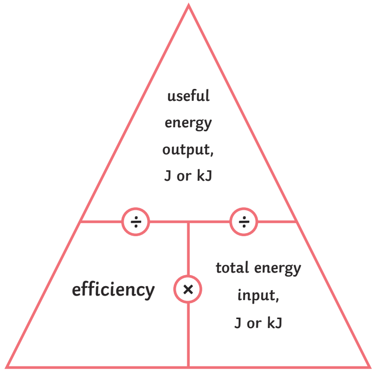


Efficiency

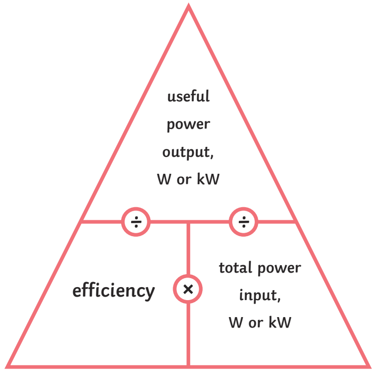
When energy is transferred, some energy is wasted. The less energy that is wasted during the transfer, the more efficient the transfer.

There are two equations to calculate efficiency:

$$\text{efficiency} = \frac{\text{useful output energy transfer}}{\text{total input energy transfer}}$$



$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$



Some energy is always wasted. Nothing is 100% efficient.

Efficiency

Non-renewable – coal, oil, gas - they will all run out, they damage the environment, but provide most of the energy.

Renewable – they will never run out, can be unreliable and do not provide as much energy.

Energy Resource	Advantages	Disadvantages
solar – using sunlight	Renewable, no pollution, in sunny countries it is very reliable.	Lots of energy needed to build, only works during the day, cannot increase power if needed.
geothermal – using the energy of hot rocks	Renewable and reliable as the rocks are always hot. Power stations have a small impact on environment.	May release some greenhouse gases and only found in specific places.
wind – using turbines	Renewable, no pollution, no lasting damage to the environment, minimal running cost.	Not as reliable, do not work when there is no wind, cannot increase supply if needed.
hydroelectric – uses a dam	Renewable, no pollution, can increase supply if needed.	A big impact on the environment. Animals and plants may lose their habitats.
wave power – wave powered turbines	Renewable, no pollution.	Disturbs the seabed and habitats of animals. Unreliable.
tidal barrages – big dams across rivers	Renewable, very reliable, no pollution.	Changes the habitats of wildlife, fish can be killed in the turbines.
biofuels	Renewable, reliable, carbon neutral.	High costs, growing biofuels may cause a problem with regards to space, clearance of natural forests.
non-renewable – fossil fuels	Reliable, enough to meet current demand, can produce more energy when there is more demand.	Running out, release CO_2, leading to global warming, and also release SO_2 which causes acid rain.

Trends in energy resources – most of our electricity is generated by burning fossil fuels and nuclear. The UK is trying to increase the amount of renewable energy resources. The governments are aware that non-renewable energy resources are running out; targets of renewable resources have been set. Electric and hybrid cars are also now on the market.

However, changing the fuels we use and building renewable power plants cost money. Many people are against the building of the plants near them and do not want to pay the extra in their energy bills. Hybrid and electric cars are also quite expensive.

Electricity – Separate Science

Required Practical

Investigating Resistance in a Wire

Independent variable: length of the wire.

Dependent variable: resistance.

Control variables: type of metal, diameter of the wire.

Conclusion: As the length of the wire increases, the resistance of the wire also increases.

Investigating Series and Parallel Circuits with Resistors

Independent variable: circuit type (series, parallel).

Dependent variable: resistance.

Control variables: number of resistors, type of power source.

Conclusion: Adding resistors in series increases the total resistance of the circuit. In a parallel circuit, the more resistors you add, the smaller the resistance.

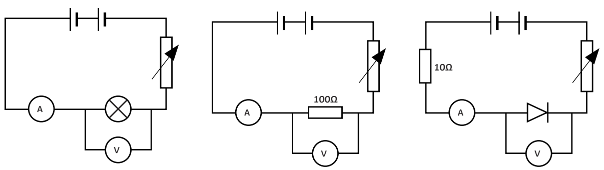
Investigating I-V Relationships in Circuits (Using a filament bulb, ohmic conductor, diode.)

Independent variable: potential difference/volts (V).

Dependent variable: current (A).

Control variable: number of components (e.g. 1 filament bulb, 1 resistor), type of power source.

Set up the circuits as shown below and measure the current and the potential difference.



Draw graphs of the results once collected.

Equations and Maths

Equations

Charge:	$Q = It$
Potential difference:	$V = IR$
Energy transferred:	$E = Pt$
Energy transferred:	$E = QV$
Power:	$P = VI$
Power:	$P = I^2R$

Maths

1kW = 1000W

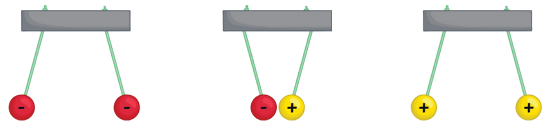
0.5kW = 500W

50 000W = 50kW

Static

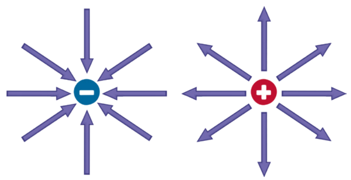
A build-up of static is caused by friction. When materials are rubbed together, the electrons move from one to the other. One material becomes positively charged and the other is negatively charged. The positive charges do not move.

Too much static can cause a spark. If the potential difference is large enough, the electrons can jump across the gap - this is the spark.



repulsion attraction repulsion

Electric charges create an **electric field**. The closer you get to the object, the **stronger** the field. The electric field can be shown by drawing field lines, they go from **positive to negative**.

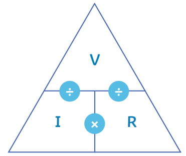


If a charged object is placed near the field, it will experience a force. The force becomes stronger as the charged object gets closer.

Resistance

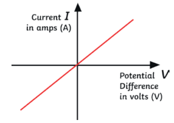
voltage (V) = current (A) × resistance (Ω)

V = IR

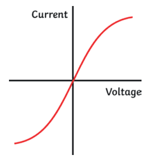


Graphs of I-V Characteristics for Components in a Circuit

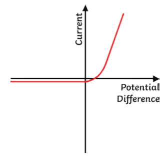
1. **Ohmic conductor**: the current is directly proportional to the potential difference - it is a straight line (at a constant temperature).



2. **Filament lamp**: as the current increases, so does the temperature. This makes it harder for the current to flow. The graph becomes less steep.



3. **Diode**: current only flows in one direction. The resistance is very high in the other direction which means no current can flow.



Current and Circuit Symbols

Current: the flow of electrical charge.

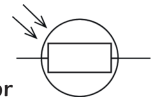
Potential difference (voltage): the push of electrical charge.

Resistance: slows down the flow of electricity.

cell		closed switch		fuse	
resistor		ammeter	A	LDR	
battery		voltmeter	V	LED	
variable resistor		bulb		thermistor	
open switch		diode			

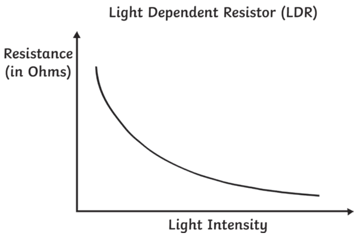
Circuit Devices

LDR – Light Dependent Resistor

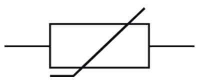


An LDR is dependent on light intensity. In bright light the resistance falls and at night the resistance is higher.

Uses of LDRs: outdoor night lights, burglar detectors.

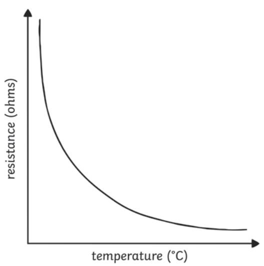


Thermistor



A thermistor is a temperature dependent resistor. If it is hot, then the resistance is less.
If it becomes cold, then the resistance increases.

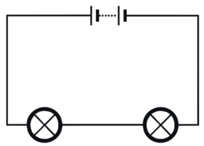
Uses of thermistors: temperature detectors.



Series and Parallel Circuits

Series Circuits

Once one of the components is broken then all the components will stop working.



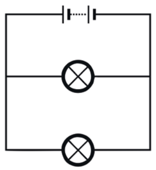
Potential difference – the total p.d. of the supply is shared between all the components. $V_{total} = V_1 + V_2$

Current – wherever the ammeter is placed in a series circuit the reading is the same. $I_1 = I_2 = I_3$

Resistance – In a series circuit, the resistance will add up to make the total resistance. $R_{total} = R_1 + R_2$

Parallel Circuits

They are much more common - if one component stops working, it will not affect the others. This means they are more useful.



Potential Difference – this is the same for all components. $V_1 = V_2$

Current – the total current is the total of all the currents through all the components. $I_{total} = I_1 + I_2 + I_3$

Resistance – adding resistance reduces the total resistance.

Charge

Electric current is the flow of electric charge. It only flows when the circuit is complete.

The **charge** is the current flowing past a point in a given time. Charge is measured in **coulombs (C)**.

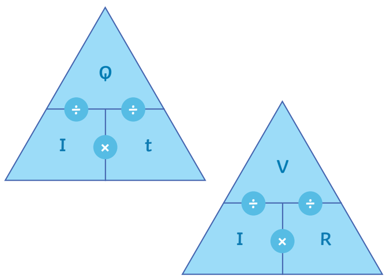
Calculating Charge

charge flow (C) = current (A) × time (s)

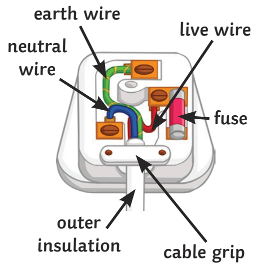
$Q = It$

potential difference = current x resistance

$V (V) = I (A) \times R (\Omega)$



Electricity in the Home



AC – alternating current. Constantly changing direction - UK mains supply is 230V and has a frequency of 50 hertz (Hz).

DC – direct current. Supplied by batteries and only flows in one direction.

Cables – most have three wires: live, neutral and earth. They are covered in plastic insulation for safety.

Live wire – provides the potential difference from the mains.

Neutral wire – completes the circuit.

Earth wire – protection. Stops the appliance from becoming live. Carries a current if there is a fault.

Touching the live wire can cause the current to flow through your body. This causes an electric shock.

Energy Transferred – this depends on how long the appliance is on for and its power.

energy transferred (J) = power (W) × time (s) $E = Pt$

Energy is transferred around a circuit when the charge moves.

energy transferred (J) = charge flow (C) × potential difference (V) $E = QV$

power (W) = potential difference (V) × current (A) $P = VI$

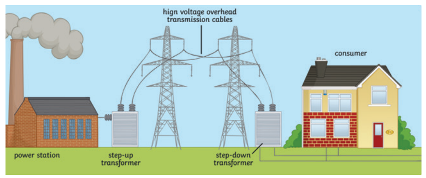
power (W) = current² (A) × resistance (Ω) $P = I^2R$

The National Grid

The National Grid is a system of **cables** and **transformers**. They transfer electrical power from the power station to where it is needed. Power stations are able to change the amount of electricity that is produced to meet the demands. For example, more energy may be needed in the evenings when people come home from work or school. Electricity is transferred at a low current, but a high voltage so less energy is being lost as it travels through the cables.

Step-up transformers – increase the voltage as the electricity flows through the cables.

Step-down transformers – decrease the potential difference to make it safe.



Unit 3: Particle Model of Matter

Required Practical

Measuring the density of a regularly shaped object:

- Measure the mass using a balance.
- Measure the length, width and height using a ruler.
- Calculate the volume.
- Use the density (p = m/V) equation to calculate density.

Measuring the density of an irregularly-shaped object:

- Measure the mass using a balance.
- Fill a eureka can with water.
- Place the object in the water - the water displaced by the object will transfer into a measuring cylinder.
- Measure the volume of the water. This equals the volume of the object.
- Use the density (p = m/V) equation to calculate density.

Density

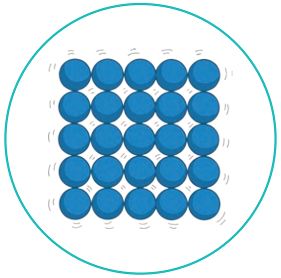
Density is a measure of how much mass there is in a given space.

Density (kg/m^3) = mass (kg) ÷ volume (m^3)

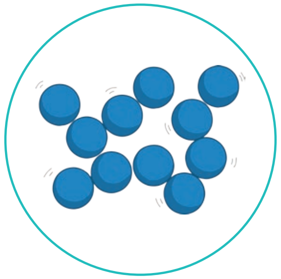
A more dense material will have more particles in the same volume when compared to a less dense material.

Particles

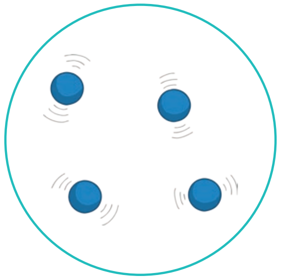
Solids have strong forces of attraction. They are held together very closely in a fixed, regular arrangement. The particles do not have much energy and can only vibrate.



Liquids have weaker forces of attraction. They are close together, but can move past each other. They form irregular arrangements. They have more energy than particles in a solid.



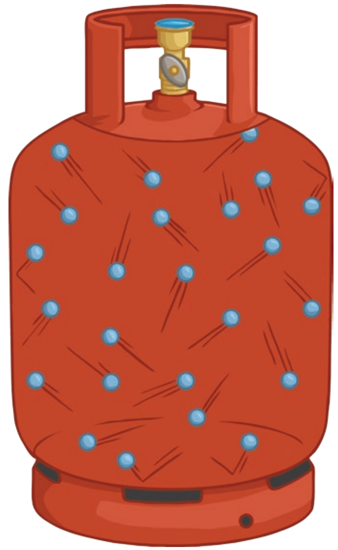
Gases have almost no forces of attraction between the particles. They have the most energy and are free to move in random directions.



Particles

Gas particles can move around freely and will collide with other particles and the walls of the container. This is the pressure of the gas.

If the temperature of the gas increases, then the pressure will also increase. The hotter the temperature, the more kinetic energy the gas particles have. They move faster, colliding with the sides of the container more often.



Density

The density of an object is 8050kg/m^3 and it has a volume of 3.4m^3 - what is its mass in kg?

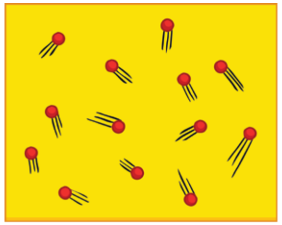
8050 = mass ÷ 3.4

8050 × 3.4 = mass

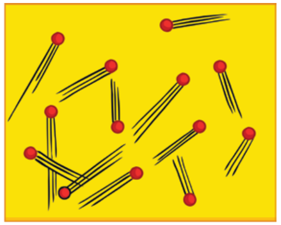
27 370kg

Internal Energy

Particles within a system have kinetic energy when they vibrate or move around. The particles also have a potential energy store. The total internal energy of a system is the kinetic and potential energy stores.



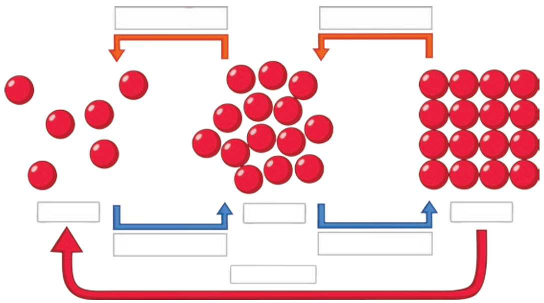
Low Temperature



High Temperature

If the system is heated, the particles will gain more kinetic energy, so increasing the internal energy.

Changing State

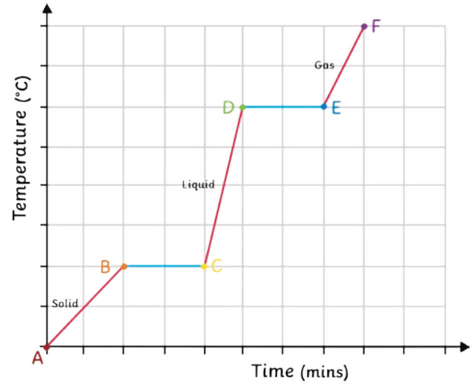


If a system gains more energy, it can lead to a change in temperature or change in state. If the system is heated enough, then there will be enough energy break bonds.

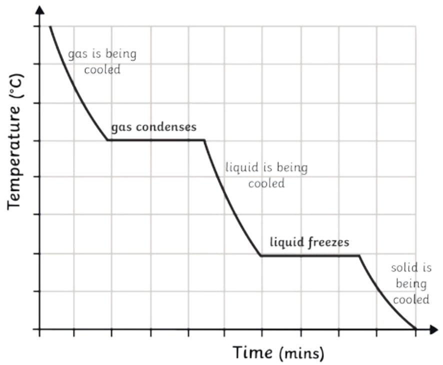
When something changes state, there is no chemical change, only physical. No new substance is formed. The substance will change back to its original form. The number of particles does not change and mass is conserved.

Specific Latent Heat

Energy is being put in during melting and boiling. This increases the amount of internal energy. The energy is being used to break the bonds, so the temperature does not increase. This is shown by the parts of the graph that are flat.



When a substance is condensing or freezing, the energy put in is used to form the bonds. This releases energy. The internal energy decreases, but the temperature does not go down.



The energy needed to change the state of a substance is called the latent heat.

Specific latent heat is the amount of energy needed to change 1kg of a substance from one state to another without changing the temperature. Specific latent heat will be different for different materials.

- solid ⟶ liquid - specific latent heat of **fusion**
- liquid ⟶ gas - specific latent heat of **vaporisation**

Specific Latent Heat Equation

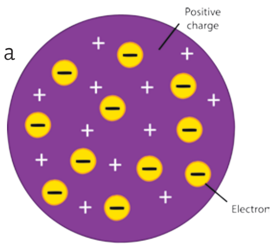
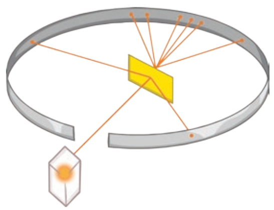
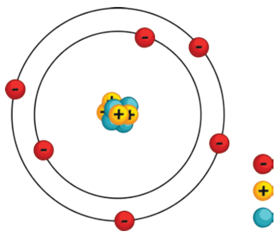
The amount of energy needed/released when a substance of mass changes state.

energy (E) = mass (m) × specific latent heat (L)

$E = mL$

Atomic Structure Knowledge Organiser

Developing the Model of the Atom

Scientist	Time	Contribution
John Dalton	Start of 19th century	Atoms were first described as solid spheres.
JJ Thomson	1897	Thomson suggested the plum pudding model – the atom is a ball of charge with electrons scattered within it.  Plum pudding model
Ernest Rutherford	1909	Alpha Scattering experiment – Rutherford discovered that the mass is concentrated at the centre and the nucleus is charged. Most of the mass is in the nucleus. Most atoms are empty space. 
Niels Bohr	Around 1911	Bohr theorised that the electrons were in shells orbiting the nucleus. 
James Chadwick	Around 1940	Chadwick discovered neutrons in the nucleus.

Isotopes

An isotope is an element with the same number of protons but a different number of neutrons. They have the same atomic number, but different mass numbers.

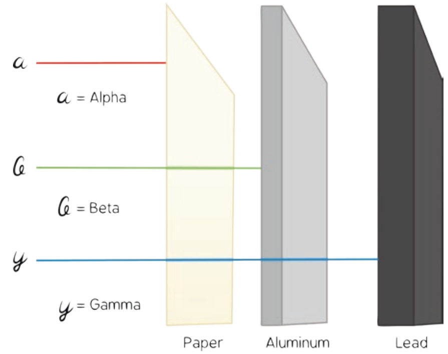
Isotope	Protons	Electrons	Neutrons
$^{1}_{1}H$	1	1	0
$^{2}_{1}H$	1	1	1
$^{3}_{1}H$	1	1	2

Some isotopes are unstable and, as a result, decay and give out radiation. Ionising radiation is radiation that can knock electrons off atoms. Just how ionising this radiation is, depends on how readily it can do that.

Beta

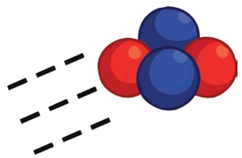
Beta radiation is a fast moving electron that can be stopped by a piece of aluminium. Beta radiation is emitted by an atom when a neutron splits into a proton and an electron.

$^{0}_{-1}e$



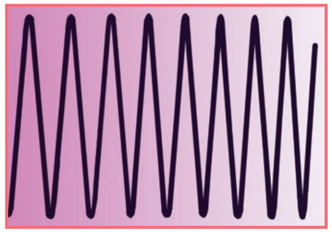
Alpha

Alpha radiation is an alpha particle emitted from the nucleus of a radioactive nuclei. It is made from two protons and two neutrons. They can't travel too far in the air and are the least penetrating – stopped by skin and paper. However, they are highly ionising because of their size.



Gamma

A gamma wave is a wave of radiation and is the most penetrating – stopped by thick lead and concrete.



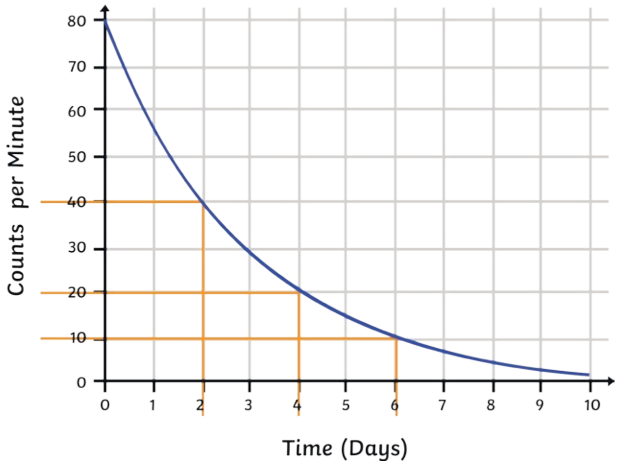
Half-life

The half-life is the time taken for the number of radioactive nuclei in an isotope to halve.

Radioactivity is a random process – you will not know which nuclei will decay. Radioactive decay is measured in becquerels Bq. 1 Bq is one decay per second.

Radioactive substances give out radiation from their nucleus.

A graph of half-life can be used to calculate the half-life of a material and will always have this shape:



Judging from the graph, the radioactive material has a half-life of two days.

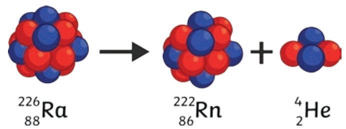
Irradiation

Irradiation occurs when materials are near a radioactive source. The source is sometimes placed inside a lead-lined box to avoid this.

People who work with radioactive sources will sometimes stand behind a lead barrier, be in a different room or use a remote-controlled arm when handling radioactive substances.

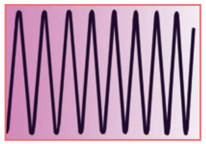
Alpha Decay Equations

An alpha particle is made of two protons and two neutrons. The atomic number goes down by two and its mass number decreases by four.



Gamma rays

There is no change to the nucleus when a radioactive source emits gamma radiation. It is the nucleus getting rid of excess energy.



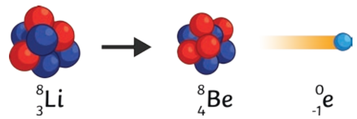
Contamination

When unwanted radioactive atoms get onto an object, it is possible for the radioactive particles to get inside the body.

Protective clothing should be worn when handling radioactive material.

Beta Decay Equations

A neutron turns into a proton and releases a an electron. The mass of the nucleus does not change but the number of protons increases.



Alpha radiation is more dangerous inside the body. It is highly ionising and able to cause a lot of damage. Outside the body it is less dangerous because it cannot penetrate the skin.

Beta radiation is less dangerous inside the body as some of the radiation is able to escape. Outside the body it is more dangerous as it can penetrate the skin.

Gamma radiation is the least dangerous inside the body as most will pass out and it is the least ionising. Gamma is more dangerous outside the body as it can penetrate the skin.

AQA GCSE Physics (Separate Science) Unit 5: Forces

Scalar and Vector Quantities

A **scalar** quantity has **magnitude** only. Examples include temperature or mass.

A **vector** quantity has both **magnitude** and **direction**. Examples include velocity.

Speed is the scalar magnitude of **velocity**.

A vector quantity can be shown using an **arrow**. The size of the arrow is relative to the magnitude of the quantity and the direction shows the associated direction.

Contact and Non-Contact Forces

Forces either **push** or **pull** on an object. This is as a result of its interaction with another object.

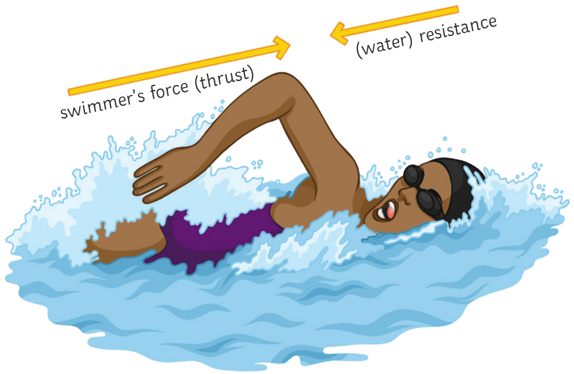
Forces are categorised into two groups:

Contact forces – the objects are touching e.g. friction, air resistance, tension and contact force.

Non-contact forces – the objects are not touching e.g. gravitational, electrostatic and magnetic forces.

Forces are calculated by the equation: **force (N) = mass (kg) × acceleration (m/s²)**

Forces are another example of a **vector quantity** and so they can also be represented by an **arrow**.



Gravity

Gravity is the natural phenomenon by which any object with mass or energy is drawn together.

- The **mass** of an object is a scalar measure of how much matter the object is made up of. Mass is measured in **kilograms (kg)**.
- The **weight** of an object is a vector measure of how gravity is acting on the mass. Weight is measured in **newtons (N)**.

weight (N) = mass (kg) × gravitational field strength (N/kg)

(The gravitational field strength will be given for any calculations. On earth, it is approximately 9.8N/kg).

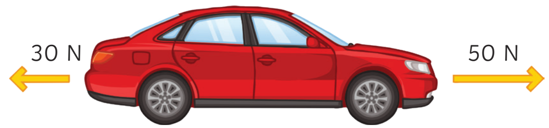
An object's **centre of mass** is the point at which the weight of the object is considered to be acting. It does not necessarily occur at the centre of the object.

The **mass** of an object and its **weight** are **directly proportional.** As the mass is increased, so is the weight. Weight is measured using a **spring-balance** (or **newton metre**) and is measured in **newtons** (N).

Resultant Forces

A **resultant force** is a single force which replaces several other forces. It has the same effect acting on the object as the combination of the other forces it has replaced.

The forces acting on this object are represented in a **free body** diagram. The arrows are relative to the magnitude and direction of the force.



The car is being pushed to the left by a force of 30N. It is also being pushed to the right by a force of 50N.

The **resultant force is 50N – 30N = 20N**

The 20N resultant force is pushing to the right, **so the car will move right.**

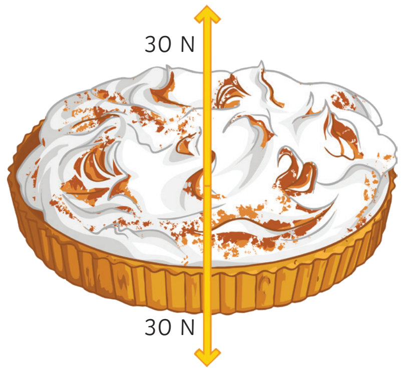
When a resultant force is not zero, an object will **change speed (accelerate or decelerate)** or **change direction (or both)**.

When an object is stationary, there are still forces acting upon it.

In this case, **the resultant force is 30N – 30N = 0N**.

The forces are in **equilibrium** and are **balanced**.

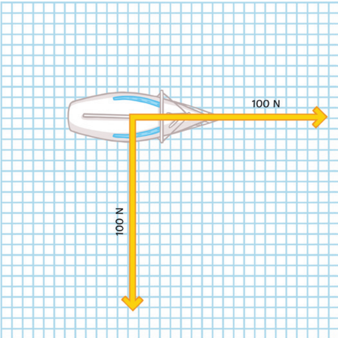
When forces are balanced, an object will either **remain stationary** or if it is moving, it will continue to move at a **constant speed**.



Resultant Forces

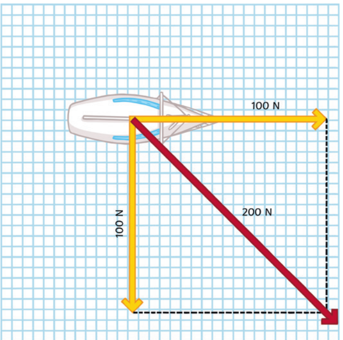
A **scale vector diagram** can be used to calculate **resultant forces** that are not acting directly opposite of one another, on a straight line.

Worked example 1:



A boat is being pulled toward the harbour by two winch motors. Each motor is pulling with a force of 100N and they are working at right angles to one another.

To find the resultant force, you would first draw construction lines from the end of each arrow parallel to the other force arrow.



Remember that the size of the arrow is representative of the size of the force being exerted.

Where the construction lines intercept indicates the direction of the resultant force: from the centre of mass through the intercept.

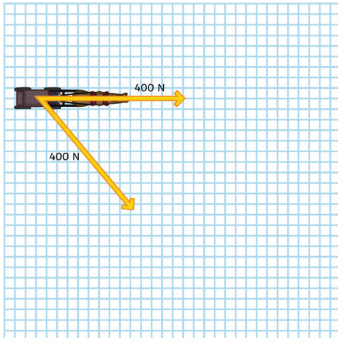
The resultant force is the sum of the forces acting so in this example, that is 200N.

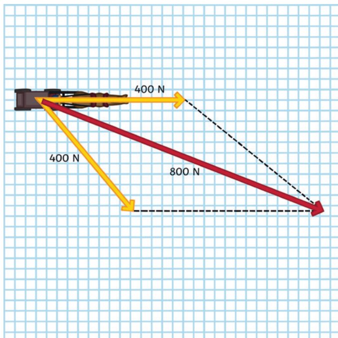
Measure the size of the arrows and make sure you draw your resultant force arrow to the correct scale so it represents the resultant force size.

Worked example 2:

A horse-drawn carriage is pulled by two horses at 400N each. One of the horses is pulling in a different direction to the other horse. Show the resultant force and direction of the horse-drawn carriage.

As before, you will need to draw construction lines from the end of each force arrow and parallel to the other one. The intercept represents the direction of the resultant force. The resultant force is the sum of the individual forces so in this example, it is 800N.





Work Done and Energy Transfer

When a force acts on an object and makes it move, there is **work done** on the object. This movement requires energy. The **input energy** could be from fuel, food or electricity for example.

The energy is **transferred to a different type of energy** when the work is done. Not all the energy transfers are useful, sometimes energy is **wasted**. For example, when car brakes are applied, some energy is wastefully transferred as heat to the surroundings. Work done against the force of **friction** always causes a **temperature rise** in the object.

Work done is calculated by this equation:

work done [*energy transferred*] **(J) = force (N) × distance moved (in the direction of the force) (m)**

Worked example

A man's car has broken down and he is pushing it to the side of the road. He pushes the car with a force of 160N and the car is moved a total of 8m. Calculate the energy transferred.

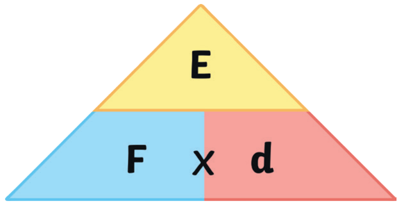
E = F × d

E = 160 × 8

E = 1280J

1 joule of energy is transferred for every 1 newton of force moving an object by a distance of 1 metre.

1J = 1Nm

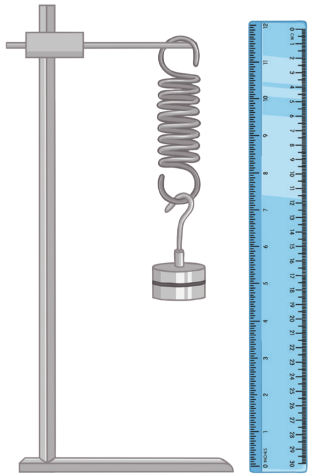


Required Practical Investigation Activity 6: Investigate the Relationship Between Force and Extension for a Spring

F = k × e

force applied (N) = spring constant (N/m) × extension (m)

You should be familiar with the equation above and the required practical shown to the right.

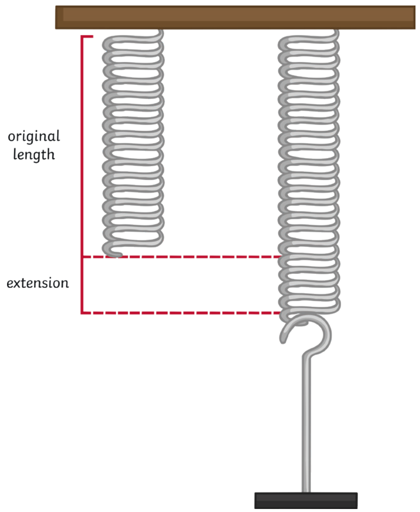


The spring constant is a value which describes the elasticity of a material. It is specific to each material. You can carry out a practical investigation and use your results to find the spring constant of a material.

1. Set up the equipment as shown.
2. Measure the original length of the elastic object, e.g. a spring, and record this.
3. Attach a mass hanger (remember the hanger itself has a weight). Record the new length of the spring.
4. Continue to add masses to the hanger in regular intervals and record the length each time.

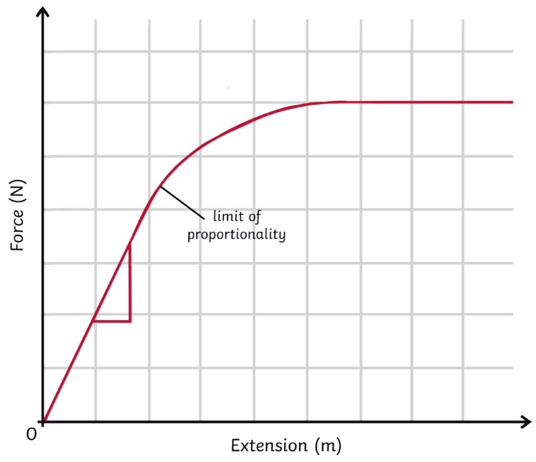
Once you have your results, you can find the extension for each mass using this formula: **spring length – original length**

The data collected is continuous so you would plot a **line graph** using the x-axis for extension (m) and the y-axis for force (N). As a result of Hooke's Law, you should have a **linear graph**. The **gradient of the graph is equal to the spring constant**. You can calculate it by rearranging the formula above or by calculating the gradient from your graph.



Spring Constant and Hooke's Law

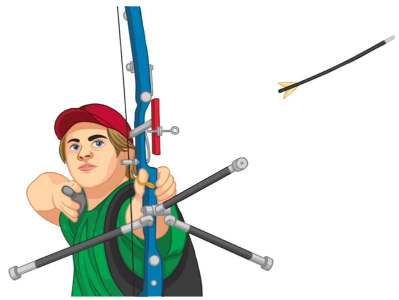
Hooke's Law describes that the extension of an elastic object is **proportional** to the force applied to the object. However, there is a maximum applied force for which the extension will still increase proportionally. If the **limit of proportionality** is exceeded, then the object becomes **permanently deformed** and can no longer return to its original shape. This can be identified on a graph of extension against force when the gradient stops being linear (a straight line) and begins to **plateau**. The limit is shown on the graph above and this is the specific object's **elastic limit**.



Forces and Elasticity

When work is done on an elastic object, such as a spring, the energy is stored as elastic potential energy.

When the force is applied, the object changes shape and stretches. The energy is stored as elastic potential and when the force is no longer applied, the object returns to its original shape. The stored elastic potential energy is transferred as kinetic energy and the object recoils and goes back to its original shape.



Work Done: Elastic Objects

Work is done on elastic objects to **stretch** or compress them.

To calculate the work done (**elastic potential energy** transferred), use this equation:

$E\ (J) = 0.5 \times k \times e^2$

(elastic potential energy = 0.5 × spring constant × extension^2)

You might need to use this equation also: $F = k \times e$

Worked example:

A bungee jumper jumps from a bridge with a weight of 800N. The elastic cord is stretched by 25m. Calculate the work done.

Step 1: find the spring constant using $F = k \times e$

Rearrange to $k = F \div e$

$800 \div 25 = 32$N/m

Step 2: use the value for k to find the elastic potential energy (work done) using $E\ (J) = 0.5 \times k \times e^2$

$0.5 \times 32 \times 25^2$

E = 10 000J

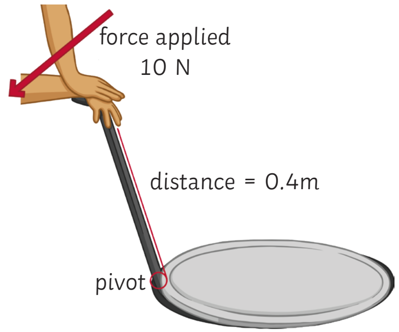
Moments, Levers and Gears

A moment is the turning effect produced by a force. To find the size of a moment, use the equation:

moment (Nm) = force (N) × distance (m)

Remember that the distance is the perpendicular distance from the pivot to the line of action of the force.

Worked example:



A crowbar is being used to lift a manhole cover. Calculate the moment produced.

$M = F \times d$

$M = 10 \times 0.4$

m = 40Nm

To increase the turning affect achieved without increasing the amount of force applied, you would need to increase the distance between the force and the pivot.

For example, if the crowbar in the example above was 0.5m, then the moment would be:

$M = F \times d$

$M = 10 \times 0.5$

M = 50Nm

Levers can be used to increase the effect of a force applied, acting as a force multiplier. Some everyday examples include:

spanner

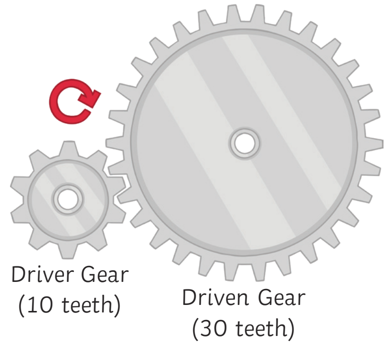
wheelbarrow

pair of scissors

A force multiplier makes it easier to do work because the same force applied at a greater distance from the pivot increases the moment produced.

A **gear** is a wheel which has 'teeth' around the circumference.

The teeth of different gears lock together and the gear can turn on an **axle**, turning the other gears it is connected to. Where the teeth meet, they must move in the same direction. This means that the gears rotate in **opposite directions**. If one gear is turning clockwise, it will turn the connected gear anticlockwise.



When gears are connected, the **same force** is applied to each; however, if they are different sizes, they will produce **different moments**. This is because the moment is calculated using the distance from the pivot (the radius of the gear) and if the gear is smaller, it will move a shorter distance. If the gear is larger, it will move a greater distance.

Worked example:

A gear has a radius of 0.25m. It turns a second gear with a radius of 1.5m. The moment of the smallest gear is 30Nm. Calculate the moment of the largest gear.

Step 1: calculate the force using $M = F \times d$

Rearrange to $F = M \div d$

$F = 30 \div 0.25$

F = 120N

Step 2: use the force to calculate the moment of the larger gear.

$M = F \times d$

$M = 120 \times 1.5$

M = 180Nm

Balanced Moments

When the anticlockwise moment on an object is equal to the clockwise moment, the **resultant moment** is zero and the object does not move or turn.

To balance moments: **total anticlockwise moments = total clockwise moments**

Worked example:

An elephant sits on a seesaw. It has a weight of 750N and is sat 2.5m from the pivot. A mouse with a weight of 60N is sitting on the other side of the seesaw. The seesaw is balanced.

What distance is the mouse from the pivot?

Step 1:	**Step 2:**	**Step 3:**
Calculate the anticlockwise moment. M = F × d = 750N × 2.5m = 1875Nm	total anticlockwise moments = total clockwise moments 1875Nm = 1875Nm	Use the value calculated for the moment to find the distance on the clockwise side. rearrange: d = M ÷ F d = 1875 ÷ 60 d = 31.25m

Pressure and Pressure Difference in Fluids

A **fluid** is any material in a state of matter which flows; it is a **liquid** or a **gas.**

The pressure in a fluid causes a force at a **right angle** (normal) to the surface.

The pressure is calculated using the equation:

$$\text{pressure (Pa)} = \frac{\text{force (N)}}{\text{surface area (m}^2\text{)}}$$

Worked example:

Find the pressure exerted by an elephant on a frozen pond. The force exerted by the elephant is 4500N and the area of the pond is 30m^2.

p = 4500 ÷ 30

p = 150Pa

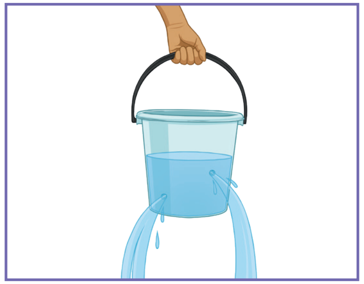
Pressure in Fluids

You can find the pressure produced by a column of liquid using the equation:

pressure (Pa) = height of column (m) × density of liquid (kg/m^3) × gravitational field strength (N/kg)

The more water above an object, then the greater the force applied and the greater the pressure exerted. Scuba divers have to monitor the pressure as they dive to ensure they are not endangering their lives by going too deep.

This can be demonstrated by placing holes in a bucket or other container of water at two different heights.



Water leaking from the hole higher up the bucket will be at a lower pressure than water leaking from the hole lower in the bucket.

When an object is **submerged partially**, it will have a greater pressure on the bottom surface than on the top surface (there is more water behind the force acting upwards). This creates an upwards resultant force called **upthrust** and this is what causes an object to float.

Atmospheric Pressure

Surrounding the earth is a layer of **air** called the **atmosphere**. Compared to the size of the planet, this layer is relatively thin. The air becomes less dense the farther from the planet's surface you are (with increasing **altitude**).

When the air molecules collide with the surface of the earth, pressure is exerted and this is called **atmospheric pressure.** The amount of air molecules above a surface **decreases** with **altitude** and so the **pressure exerted** also **decreases** with increasing height.

Velocity

Velocity is a **vector** quantity. It is the **speed** of an object in a given **direction**.

Circular Motion (Higher tier only)

Objects moving in a **circular path** don't go off in a straight line because of a **centripetal** force caused by another force acting on the object.

For example, a car driving around a corner has a centripetal force caused by **friction** acting between the surface of the road and the tyres. When the Earth orbits around the Sun, it is held in orbit by **gravity** which causes the centripetal force.

When an object is moving in a circular motion, its **speed** is **constant.** Its **direction changes** constantly and because direction is related to **velocity**, this means that the velocity of the object is constantly changing too. The changes in velocity mean that the object is **accelerating**, even though it travels at a constant speed.

The acceleration occurs because there is a **resultant force** acting on the object. In this case, the resultant force is the velocity, which is greater than the centripetal force acting.

Forces and Motion: Distance vs Displacement

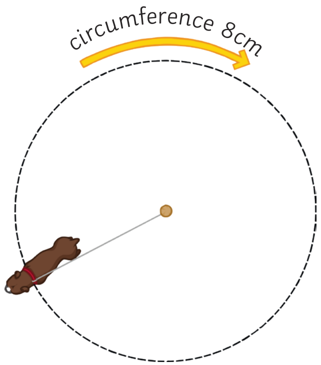
Distance is a **scalar** quantity. It measures how far something has moved and does not have any associated direction.

Displacement is a **vector** quantity. It measures how far something has moved and is measured in relation to the direction of a straight line between the starting and end points.

E.g. A dog is tethered to a post. It runs 360˚ around the post three times. Each 360˚ lap is 8m

distance = 8 × 3 = 24m

displacement = 0m (The dog is in the same position as when it started.)



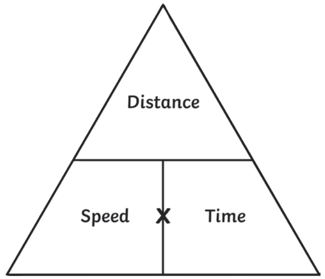
Speed

You should be able to recall the typical speed of different transportation methods.

Activity	Typical Value
walking	**1.5m/s**
running	**3m/s**
cycling	**6m/s**
driving a car	25mph (40km/h)
train travel	60mph (95km/h)
aeroplane travel	550mph (885km/h)
speed of sound	*330m/s*

These values are average only. The speed of a moving object is rarely constant and always fluctuating.

speed = distance ÷ time



You should be able to use this equation and rearrange it to find the distance or time.

Worked example:

John runs 5km. It takes him 25 minutes. Find his average speed in metres per second.

Step 1: convert the units

km → m (×1000) = 5000m

min → s (×60) = 1500s

Step 2: calculate s = d ÷ t

s = 5000 ÷ 1500

s = 3.33m/s

Worked example 2:

Zi Xin has driven along the motorway. Her average speed is 65mph. She has travelled 15 miles. How long has her journey taken? Give your answer in minutes.

Step 1: calculate t = d ÷ s

t = 15 ÷ 65

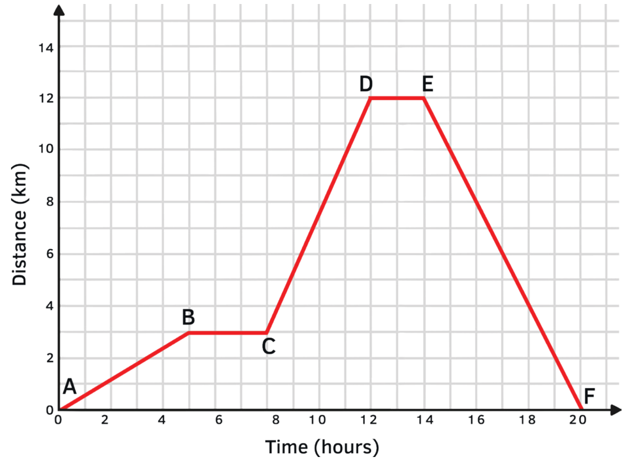
t = 0.23 (hours)

Step 2: convert units

hr → min (×60) = 13.8 minutes

Distance-Time and Velocity-Time Graphs

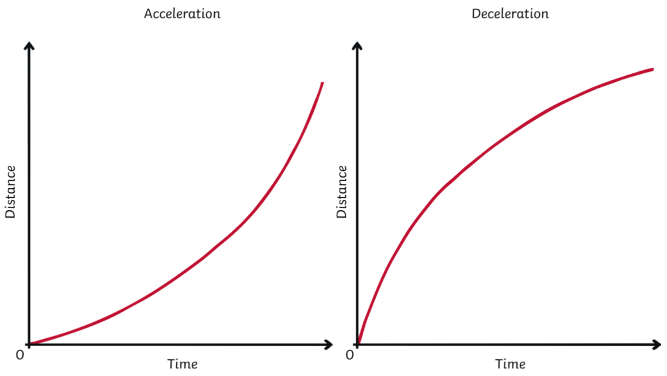
When an object travels in a **straight line**, we can show the distance which has been covered in a **distance-time graph**.



You should be able to understand what the features of the two types of graph can tell you about the motion of an object.

Graph Feature	Distance-Time Graph	Velocity-Time Graph
x-axis	time	time
y-axis	distance	velocity
gradient	speed	acceleration (or deceleration)
plateau	stationary (stopped)	constant speed
uphill straight line	steady speed moving away from start point	acceleration
downhill straight line	steady speed returning to the start point	deceleration
uphill curve	acceleration	increasing acceleration
downhill curve	deceleration	increasing deceleration
area below graph		distance travelled

Changing Speed on a D-T graph



When the graph is a **straight line**, it is representing a **constant speed**. A **curve** represents a changing speed, either **acceleration** or **deceleration**. The speed at any given point can be calculated by drawing a **tangent** from the curve and finding the **gradient** of the tangent.

Terminal Velocity

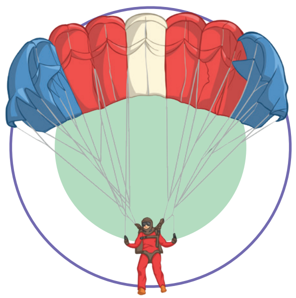
When an object begins moving, the force **accelerating** the object is much greater than the force resisting the movement. A resistant force might be **air resistance** or **friction**, for example.

As the **velocity** of the object increases, the force **resisting** the movement also increases. This causes the acceleration of the object to be reduced gradually until the forces become **equal** and are **balanced**. This doesn't cause the object to stop moving. As the object is already in motion, balanced forces mean it will continue to move at a **steady speed**. This steady speed is the maximum that the object can achieve and is called the **terminal velocity**.

The terminal velocity of an object depends on its shape and weight. The shape of the object determines the amount of resistant force which can act on it. For example, an object with a large surface area will have a greater amount of resistance acting on it.

Consider a skydiver and his parachute. When the skydiver first jumps from the aeroplane, he has a small area where the air resistance can act. He will fall until he reaches a terminal velocity of approximately 120mph.

After the skydiver releases his parachute, the shape and area has been changed and so the amount of air resistance acting is increased. This causes him to decelerate and his terminal velocity is reduced to about 15mph. This makes it a much safer speed to land on the ground.



Acceleration

Acceleration can be calculated using the equation:

$$\textbf{acceleration (m/s}^2\textbf{)} = \frac{\textbf{change in velocity (m/s)}}{\textbf{time taken (s)}}$$

Worked example:

A dog is sitting, waiting for a stick to be thrown. After the stick is thrown, the dog is running at a speed of 4m/s. It has taken the dog 16s to reach this velocity. Calculate the acceleration of the dog.

$a = \Delta v \div t$

$a = (4-0) \div 16$

$A = 0.25 m/s^2$

Changes in velocity due to acceleration can be calculated using the equation below. This equation of motion can be applied to any moving object which is travelling in a **straight line** with a **uniform acceleration**.

Final velocity^2 (m/s) – initial velocity^2 (m/s) = 2 × acceleration (m/s^2) × displacement (m)

or

$$v^2 - u^2 = 2as$$

Worked example:

A bus has an initial velocity of 2m/s and accelerates at 1.5m/s^2 over a distance of 50m. Calculate the final velocity of the bus.

Step 1: rearrange the equation: $v^2 - u^2 = 2as$

$v^2 = 2as + u^2$

Step 2: insert known values and solve

$v^2 = (2 \times 1.5 \times 50) + 2^2$

$v^2 = (150) + 4$

$v^2 = 154$

$v = \sqrt{154}$

$v = 12.41 m/s$

Stopping Distance

The **stopping distance** of a vehicle is calculated by:

stopping distance = thinking distance + braking distance

Reaction time is the time taken for the driver to respond to a hazard. It varies from 0.2s to 0.9s between most people.

Reaction time is affected by:

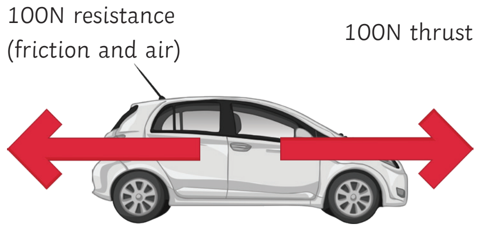
- **tiredness**
- **drugs**
- **alcohol**
- **distractions**

You can measure human reaction time in the lab using simple equipment: a metre ruler and stopwatch can be used to see how quickly a person reacts and catches the metre ruler. The data collected is quantitative and you should collect repeat readings and calculate an average result.

Newton's Laws of Motion: Newton's First Law

If the resultant force acting on an object is zero…

- **a stationary object will remain stationary.**
- **a moving object will continue at a steady speed and in the same direction.**



Inertia – the tendency of an object to continue in a state of rest or uniform motion (same speed and direction).

Newton's Laws of Motion: Newton's Second Law

The acceleration of an object is proportional to the resultant force acting on it and inversely proportional to the mass of the object

resultant force (N) = mass (kg) × acceleration (m/s^2)

Inertial mass – how difficult it is to change an objects velocity. It is defined as the ratio of force over acceleration.

Newton's Laws of Motion: Newton's Third Law

When two objects interact, the forces acting on one another are always equal and opposite.

For example, a book laid on a table is being acted upon by at least two forces: the downward pull of gravity and the upward reaction force from the table surface. The forces are equal and opposite so the book does not move. We describe the forces as being **balanced**.

Momentum

momentum (N) = mass (kg) × velocity (m/s)

The law of conservation of mass (in a closed system) states that the total momentum **before** an event is equal to the total momentum **after** an event.

Worked example:

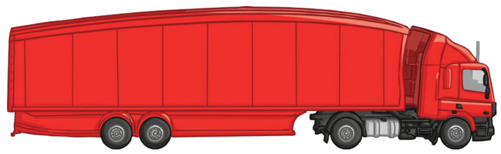
Calculate the momentum of a 85kg cyclist travelling at 7m/s.

p = m × v

p = 85kg × 7m/s

p = 595kg m/s

Worked example: 2



A lorry with a mass of 12 000kg, travelling at 20m/s, collides with a stationary car with a mass of 1500kg. After the collision, the vehicles move off together. Calculate their velocity.

Step 1: find the momentum of each vehicle before the collision.

Calculate the momentum of the lorry:

p = m × v

p = 12 000 × 20 = 240 000kg m/s

Calculate the momentum of the car:

p = m × v

p = 1500 × 0 = 0kg m/s

Braking Distance

The **braking distance** is the distance travelled by a vehicle once the **brakes are applied** and until it reaches a full stop.

Braking distance is affected by:

- **adverse weather conditions** (wet or icy)
- **poor vehicle condition** (brakes or tyres)

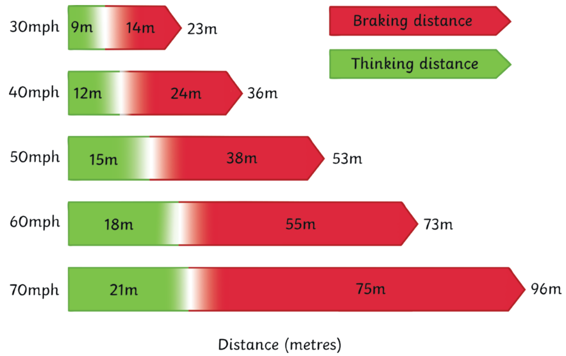
When **force** is applied to the brakes, **work is done** by the **friction** between the car wheels and the brakes.

The work done reduces the **kinetic energy** and it is transferred as **heat** energy, increasing the **temperature** of the brakes.

increased speed = increased force required to stop the vehicle

increased braking force = increased deceleration

Large decelerations can cause a huge increase in **temperature** and may lead to the **brakes overheating** and the driver **losing control** over the vehicle



Step 2: find the total momentum before the collision.

total momentum before = 240 000 + 0 = 240 000kg m/s

Step 3: use the law of conservation of momentum and rearrange the equation.

total momentum before collision = total momentum after collision

$\frac{p}{m} = v$

240 000kg m/s ÷ (12 000 + 1500) = 17.78m/s.

Worked example: 3

A cannon fires a 5kg cannonball at a velocity of 90m/s. The cannon recoils at a velocity of 2m/s after the explosion. Calculate the mass of the cannon.

Step 1: find the total momentum before the explosion.

p = m × v (for the cannonball)

p = 5 × 90 = 450kg m/s

Although you don't have all the information to calculate the momentum of the cannon, you know it is zero because it is stationary and therefore has a velocity of zero. Since momentum is mass × velocity, you know the momentum will be zero regardless of the mass.

total momentum before = 450kg m/s

Step 2: use the law of conservation of momentum and rearrange the equation.

total momentum before explosion = total momentum after explosion

$\frac{p}{v} = m$

450kg m/s ÷ 2m/s = 225kg

Changes in Momentum

When a force acts on a **moving** or **moveable** object there is a **change of momentum**.

The equations for calculating **force** and **acceleration** can be combined:

$$F = m \times a \text{ and } a = (v - u) \div t$$

To give:

force(N) = change in momentum (kg m/s) ÷ time taken (s)

or

$$F = \frac{m\Delta v}{\Delta t}$$

This equation tells you that the f**orce is equal to the rate of change of momentum** in the object.

Car Safety Features

When people are travelling in a moving car, they have momentum. If the car were to crash and become stationary all of a sudden, the passengers would lose all their momentum. This would result in a large force being exerted; therefore, it is important to change the momentum gradually.

This is done by the seatbelts and the air bags which are fitted into vehicles.

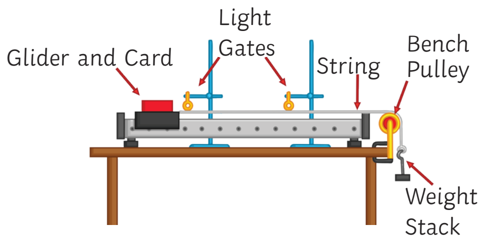
An airbag is also designed to reduce the momentum. The air bag is filled with air as is it deployed and has a small hole inside. As the person makes contact with the airbag, the air is slowly released from the hole and the person is slowed down more gradually.

The force exerted on the passenger is reduced because the time taken to slow them down is increased.

Required Practical Investigation 7

Aim: investigate the effect of varying the force on the acceleration of an object of constant mass, and the effect of varying the mass of an object on the acceleration produced by a constant force.

You may be given any of the following apparatus set-ups to conduct these investigations:



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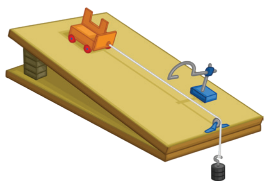

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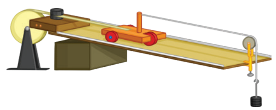


Something is a **fair test** when **only** the independent variable has been allowed to affect the dependent variable.

The independent variable was **force**.

The dependent variable was **acceleration**.

The control variables were:

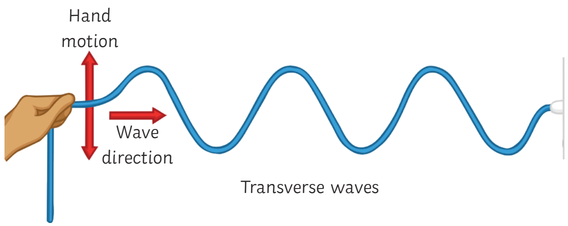
- **same total mass**
- **same surface/glider/string/pulley (friction)**
- **same gradient if you used a ramp**

AQA GCSE Physics (Separate Science) Unit 6: Waves

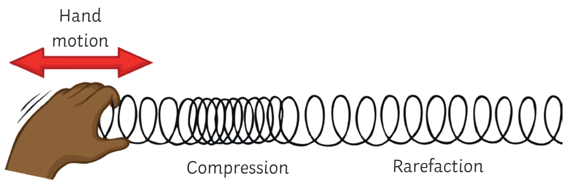
Transverse and Longitudinal Waves

Waves can be either **transverse** or **longitudinal**.

In a transverse wave, the vibrations are at a right angle (**perpendicular**) to the direction of the energy transfer. The wave has **peaks** (or crests) and **troughs**. Examples include **water waves** and **light waves**.



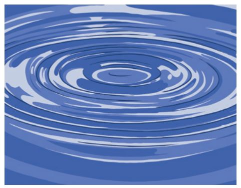
In a longitudinal wave, the vibrations are in the same direction (**parallel**) as the energy transfer. The wave has areas of **compression** and **rarefaction**. Examples of this type of wave are **sound waves**.



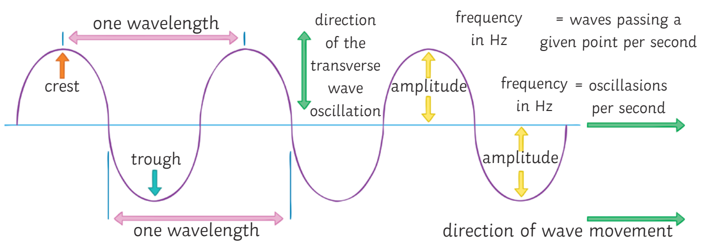
Longitudinal waves

When a wave travels, energy is transferred but the matter itself does not move. Particles of water or air vibrate and transfer energy but do not move with the wave.

This can be shown by placing a cork in a tank of water and generating ripples across the surface. The cork will bob up and down on the **oscillations** of the wave but will not travel across the tank.



Properties of Waves



The **frequency** of a wave is the number of waves which pass a given point every second.

time period (s) = 1 ÷ frequency (Hz)

t = 1 ÷ f

The **wave speed** is how quickly the energy is transferred through a medium (how quickly the wave travels).

wave speed (m/s) = frequency (Hz) × wavelength (m)

v = f × λ

The speed of **sound waves** travelling through air can be measured by a simple method. One person stands a measured distance from a large flat wall, e.g. 100m. The person then claps and another person measures the time taken to hear the echo. The speed of the sound can then be calculated using the equation

speed = distance × time.

Remember the distance will be double because the wave has travelled to the wall and back again. It is important to take several measurements and calculate the average to reduce the likelihood of human error.

Sound Waves in Different Medium

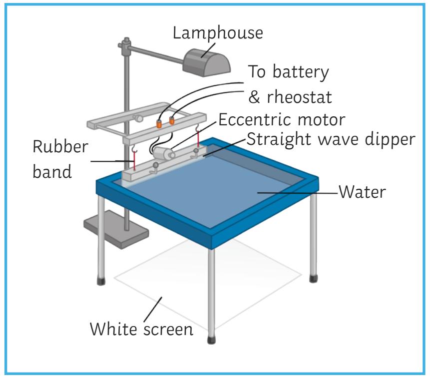
How quickly sound waves can travel through a medium is determined by the **density** of the medium (material).

Sound waves will travel faster through a solid than a liquid as the spaces between the particles are smaller. This means that the **vibrations** and **energy** can be passed along the particles more quickly. In a gas, the transmission of sound is even slower as the space between the particles is greater.

The speed of sound in air is 330m/s.

Required Practical Investigation 8

Aim: make observations and identify the suitability of apparatus to measure the frequency, wavelength and speed of waves in a ripple tank and waves in a solid, and take appropriate measurements.



The **ripple tank apparatus** shown is the most commonly used for this investigation. It is likely you will work in groups or observe the investigation as a demonstration by your teacher.

Method (assuming the apparatus is already set-up):

Turn on the power and observe the waves. Make any necessary adjustments to the equipment so that the waves are clear to observe (alter the voltage supplying the motor). **N.B. The lowest frequency setting on the motor will ensure that the waves measurements can be made more easily.**

To measure the **wavelength**, use the metre ruler and make an estimate quickly. You may want to use a **stroboscope** and freeze the wave patterns to make measurements.

Record 10 wavelengths and calculate the **average** value.

Required Practical Investigation 8 (continued)

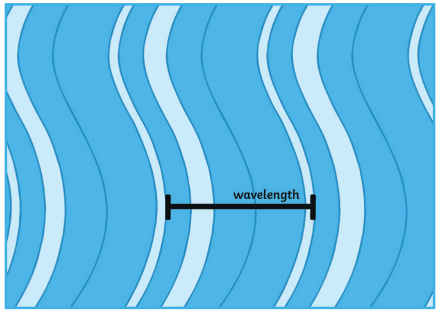
To measure the wave **frequency**, mark a given point onto the white paper and **count** the number of waves which pass the point within **10 seconds**. Divide your answer by 10 to find the number of **waves per second**.

Record 10 frequencies and calculate the **average** value.

To calculate the wave speed, use this formula:

speed = frequency × wavelength

Remember: the wavelength is the distance between one peak (or crest) of a wave and the next peak.



Required Practical Investigation 9

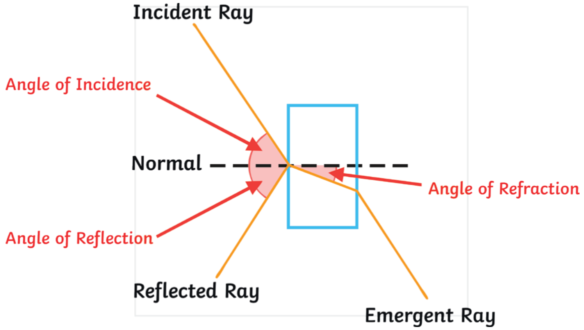
Aim: investigate the reflection of light by different types of surface and the refraction of light by different substances.

Method:

1. In a darkened room, set up the ray box on a flat surface and insert the filter to produce a single ray of light.
2. Place a glass block in the centre of a piece of plain A3 paper.
3. Draw a line around the glass block.
4. Draw a line at 90°C to the glass block and label the line normal, as shown in the diagram.
5. Position the ray box so the ray of light hits the glass at an angle.
6. Using a pencil, draw the incidence, reflected and emergent rays as shown in the diagram.
7. Remove the glass block and draw the refracted ray going through the block.
8. Using a protractor, measure the angles of incidence, reflection and refraction. Record your results.
9. Repeat the experiment by placing a clear acrylic block on the A3 paper in the same position as the glass block.
10. The incident ray must follow the same line as before. Draw the reflected and refracted rays and measure using a protractor.
11. Collect four sets of results from other members of the class.

The law of reflection states:

angle of incidence = angle of reflection



Risk assessment:

The ray box will become hot during use and may cause minor burns. To prevent this, you should not touch the lamp and ensure you allow time for the ray box to cool after use.

You will be working in a semi-dark environment which means there is a higher risk of trips or falls. You should ensure your working space is clear of bags and coats, and that stools are tucked under desks before you start your investigation.

Required Practical Investigation 10

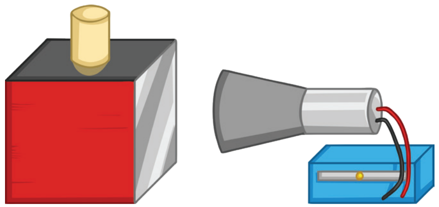
Aim: investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface.

In this investigation, you are finding out which type of surface emits the most **infrared** radiation:

- **dark and matt**
- **dark and shiny**
- **light and matt**
- **light and shiny**

Method:

1. Place the **Leslie cube** on a heatproof mat.
2. Once the kettle has boiled, fill the Leslie cube with hot water.
3. Ensuring that the **thermometer** or the **infrared detector** is an **equal distance** from each of the surfaces (in turn) on the Leslie cube, measure the amount of infrared radiation emitted.
4. Repeat the experiment twice more to collect three results for each surface.

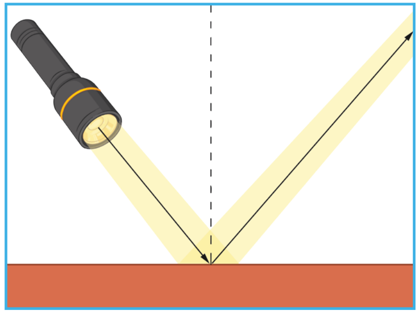


Reflection of Waves

When a **wave** comes into contact with a **surface** or a **boundary** between two media (different materials), it can be **reflected** or it can be **absorbed**.

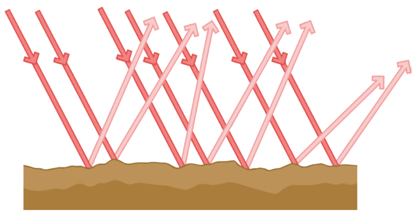
What happens depends on the properties of the surface the wave hits.

Specular reflection occurs when a wave is reflected in a **single direction** from a perfectly **smooth surface**.

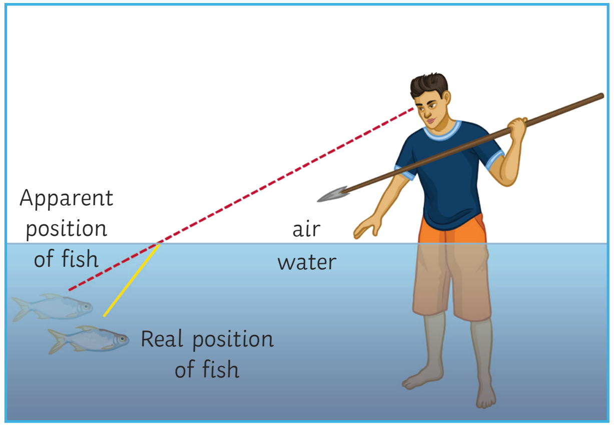


angle of incidence = angle of reflection (i = r)

Diffuse reflection occurs when a wave is reflected in **many directions** and happens at a rough or **uneven surface**.



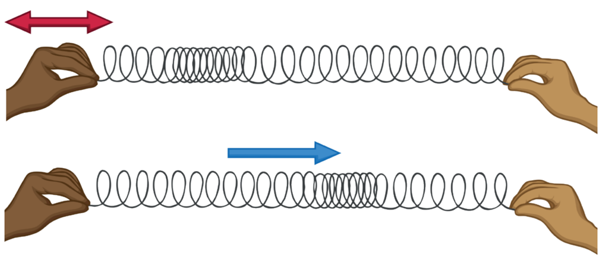
Refraction occurs when a wave **changes direction**, usually at the boundary or two different materials. The **density** of the material affects the **speed** at which the wave can travel through it. When a wave passes from a more dense material to a less dense material, it speeds up and so will bend.



Imagine a car travelling across a muddy river at an angle. As it approaches the bank of the river, one of the wheels will be on the dry bank while the other is still in the mud. The wheel on the dry bank will move faster than the one still in the mud and it will change direction.

Sound Waves (Higher tier only)

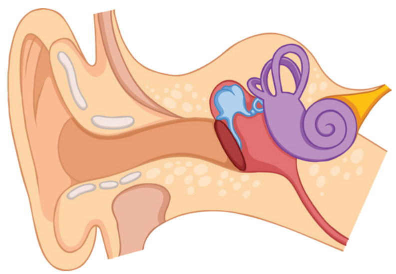
When an object vibrates, it can cause a **sound wave**. Remember, a sound wave is a **longitudinal** wave:



A sound wave can travel through a solid material. This is because the space between the particles is so small (almost non-existent) and the vibrations are transmitted more quickly than in liquids or gases.

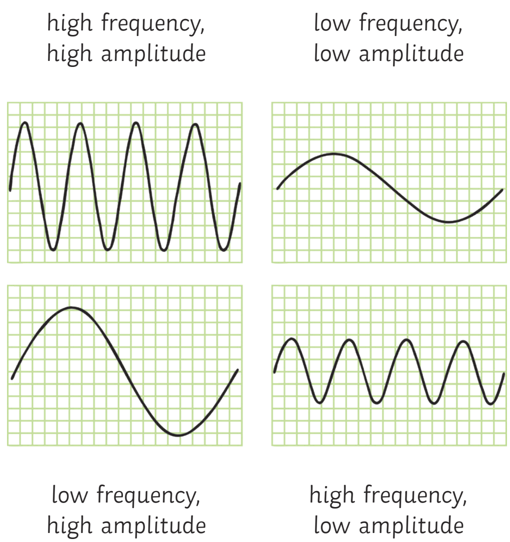
The speed of sound in air is about 330m/s. As the majority of space is a **vacuum** (no particles), sound waves do not travel in space.

Sound waves within the range of **20Hz to 20kHz** can usually be detected by the **human ear**.



Vibrations are passed along air particles down the ear canal and to the ear drum. The ear drum vibrates and transmits this to the small ear bones and then along the cochlea. The cochlea carries the vibrations to the auditory nerve which carries the sound wave as an electrical impulse to the brain.

Characteristics of a sound wave can be identified from an **oscilloscope** trace of the sound wave. The trace shows oscillations and wavelength of the sound wave. A **shorter wavelength** results in a **high-pitched** (high frequency) sound. A **greater height** of oscillations indicates a **higher amplitude** (volume) of the sound wave.



Waves for Detection and Exploration (Higher tier only)

Waves can be used to detect objects underwater, in the earth and even inside the human body.

Sonar systems used to explore **deep seas** use **high-frequency sound waves**. A sound wave is sent out from the device through the water and the **time taken** for the pulse to **reflect** from the surface is measured. The time taken with the speed of **sound in water** is used to find the **distance** of the object.

The equation used is:

distance (m) = speed (of sound) (m/s) × time (s)

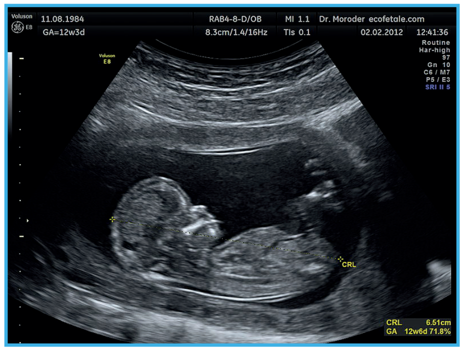
Volcanoes, earthquakes and explosions cause **seismic** waves to travel through the earth. There are two different types of seismic waves: **S-waves** and **P-waves**.

- P-waves are longitudinal waves which travel relatively quickly through solids and liquids.
- S-waves are transverse waves and they travel slower and only in solids.

Seismic waves can **change direction** when they are **reflected** or **refracted** at the boundary of different media (solid, liquid or gas). The **epicentre** of an earthquake can be found by calculating the difference in time taken for S- and P-waves to reach a certain point. Since the waves can change direction, at least three points are used to **triangulate** the data and pinpoint the source (where they all intercept).

The study of seismic waves has given scientists new **evidence** about the structure of the earth in parts which are not visible for direct observations.

Ultrasound waves are sound waves which have a **higher frequency** than the range which is detectable by the human ear. When the waves reach a boundary between different media, they are **partially reflected** and a detector is used to measure the time taken and calculate the distance. Ultrasound is used for **medical** and **industrial imaging**.



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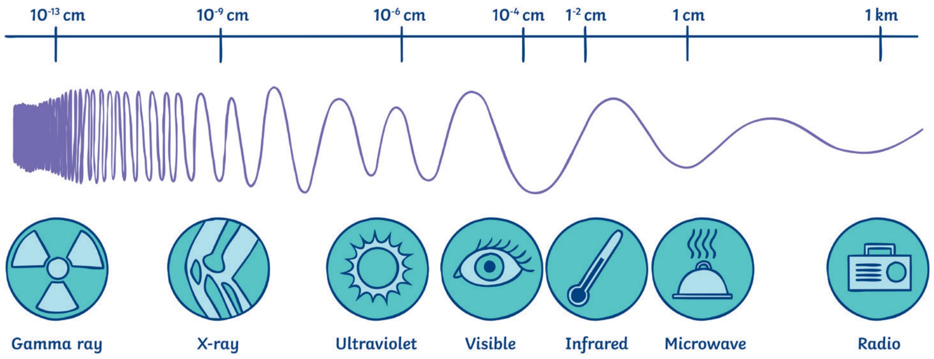
The Electromagnetic Spectrum

Electromagnetic waves transfer energy from a source to an **absorber** as **transverse** waves. The different waves are grouped depending on their **frequency** and form a continuous spectrum known as the **electromagnetic spectrum**. Each of the frequencies of waves travel at the same **velocity** and can pass through a **vacuum** as well as **air**.



Frequency	Wave	Use	Other Information
Low ↑	radio waves	Communication via television and radio, and satellite communications.	Easily transmitted through air and can be reflected to change their direction. Harmless if absorbed by the human body. Are reflected back off the atmosphere and cannot pass through into space.
	microwaves	Communications including satellite communications and cooking food.	When the molecules absorb microwaves, their internal energy increases. This can be harmful when internal body cells become heated by over exposure to microwaves. Can pass through the atmosphere and into space.
	infrared	Short-range communications (remote controls), electrical heaters, cooking food, optical fibres, security systems and thermal imaging cameras.	It can cause burns to skin.
	visible light	Used for lighting, photography and fibre optics.	Frequency range that is detectable by the human eye.
	ultraviolet	Sterilising water and killing bacteria. Detecting forged bank notes.	Causes skin tanning and can lead to burns or skin cancer.
	X-rays	Medical imaging and airport security scanners.	Very little energy is absorbed by body tissues. Instead, it is transmitted through the body. These waves can lead to gene mutation and cancer.
↓ High	gamma rays	Sterilising medical equipment or food and treatment for some cancers.	

You can remember the order of the electromagnetic spectrum easily with the phrase:

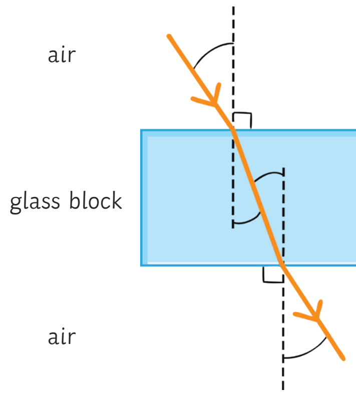
Roman men invented very unusual X-ray guns.

Properties of Electromagnetic Waves

You should be able to complete or construct a **ray diagram** to show how a wave is **refracted** at the boundary of a different medium.

As the wave moves **to** a more dense medium (e.g. from gas to solid), it slows down and bends so that the angle from the normal becomes smaller. The angle of incidence is larger than the angle of refraction.

As the wave moves **from** a more dense medium (e.g. from solid to gas), it speeds up and bends so that the angle from the normal becomes larger. The angle of refraction is larger than the angle of incidence.



The angle at which a wave enters the glass block is equal to the angle that it leaves the glass block (when entering and leaving the same medium); however, if a wave crosses a boundary between two mediums at an angle of 90˚C, then it will not change direction but instead carry on in a straight line.

Gamma rays occur as the result of changes to the nuclei of atoms and atoms themselves. It is a form of radiation and the waves can be generated and absorbed across a wide range of frequencies.

UV, X-rays and **gamma** are all types of **radiation** and can be **harmful** to human health; they cause damage to human body tissues. The severity of the damage caused depends on the dose of radiation a tissue or cell is exposed to. **Radiographers** and dentists who routinely carry out X-ray examinations wear a device to monitor the amount of exposure and ensure they are within a **safe limit**.

X-rays and gamma rays are **ionising** and can cause **mutations** to genes which may result in **cancer**.

UV waves can cause the skin to burn and age prematurely. UV exposure also increases the risk of developing **skin cancer**.

Radio Waves (Higher tier only)

Oscillations in **electrical circuits** can produce **radio waves** which when absorbed by a conductor, produce an **alternating current**.

The alternating current has the same **frequency** as the radio wave and so information can be coded for transmission. This is how **television** and **radio** are broadcast.

Temperature of the Earth (Higher tier only)

The temperature of the earth depends on:

- The rate at which **light** radiation and **infrared** radiation are **absorbed** by the **earth's surface** and **atmosphere**.
- The rate at which **light** radiation and **infrared** radiation are **emitted** by the **earth's surface** and **atmosphere**.

Light and infrared radiation absorbed by the earth cause the **internal energy** of the planet to **increase** and in turn, the surface of the earth **increases in temperature**.

Energy from the surface of the earth can be transferred to the atmosphere by **conduction** and **convection**.

The **infrared** radiation **emitted** from the earth's surface will either travel through the atmosphere and back into **space** or it will be **absorbed** (and **reflected**) by the **greenhouse gases** in the earth's atmosphere.

Visible Light

The colours of the **visible spectrum** can be remembered with the rhyme **Richard Of York Gave Battle In Vain** (red – orange – yellow – green – blue – indigo – violet).

These are all the **wavelengths** which are visible and detectable by the **human eye**. Each colour has a narrow range of wavelength and frequency within the spectrum.

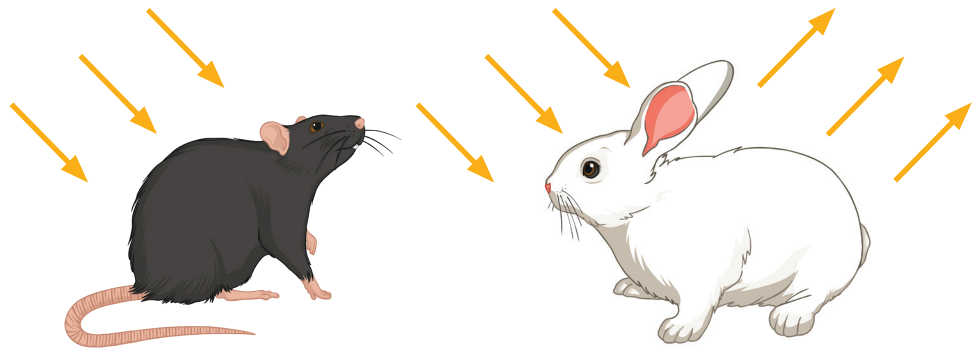
White light is the combination (full spectrum) of wavelengths in the visible light region of the electromagnetic spectrum.

A **colour filter** absorbs some wavelengths and only transmits certain wavelength(s). This means that a filter will absorb some colours and transmit others.

For example, a red filter absorbs all other colours in the spectrum except red, which it transmits.

An object which is **transparent** (see-through) or **translucent** (partially see-through) can transmit light.

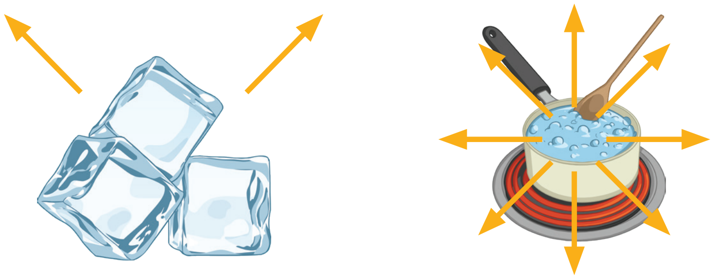
Opaque objects reflect and absorb light. The wavelengths which are reflected or absorbed determine the colour which the object is perceived.



For example, an object which absorbs all wavelengths will appear black. An object which reflects all wavelengths will appear white. An object which reflects only green colour wavelengths and absorbs the others will appear green.

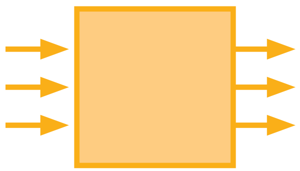
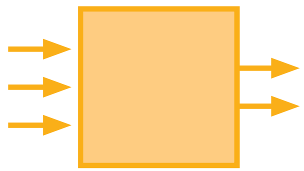
Black Body Radiation

All objects **emit** and **absorb infrared radiation**. The hotter an object is, the greater the amount of radiation emitted.



An object which absorbs all the radiation it is exposed to is called a **perfect black body**. No radiation is reflected from or transmitted through it. A perfect black body would be the most **effective emitter** as an object which is a good absorber is also a good emitter.

(Higher tier only)

		
An object **absorbing and emitting infrared radiation** at the **same rate** has a **constant temperature**.	An object **emitting more than it is absorbing** will **decrease** in **temperature**.	An object **absorbing more than it is emitting** will **increase** in **temperature.**

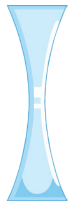
Lenses

Lenses use **refraction** in order to work. **Projectors, microscopes** and **telescopes** all use lenses to allow an object or image to be enlarged or viewed more easily.

The **human eye** contains a lens which enables us to see objects at a range of distances.

Depending on the type of **lens**, the light waves will be **refracted** differently to produce a different image.

The two main lenses are **convex lenses** and **concave lenses**. The table below compares them briefly.

convex lens	**Lens**	concave lens
	**Ray Diagram**	
	**Illustration**	
Causes parallel waves to **converge** at the principal focus.	**Action**	Causes parallel waves to **diverge** from the principal focus.
real or virtual	**Type of Image**	always virtual

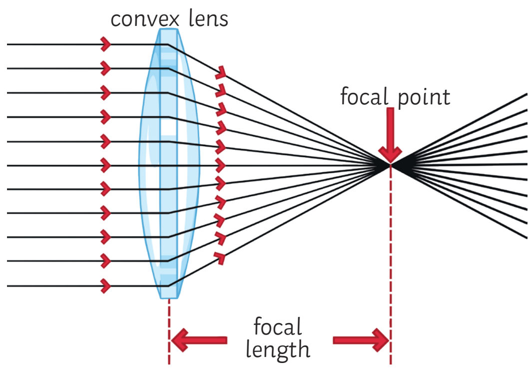
A **real image** is when light reflected from an object **converges** to form an image on a surface. For example, on the retina of the human eye.

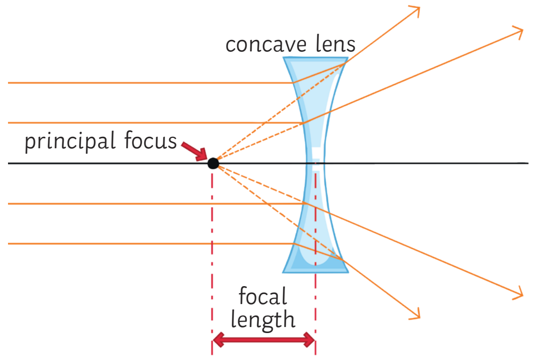
A **virtual image** occurs when the light waves are **diverging** and so appears to be coming from a different place. A virtual image cannot be projected onto a screen. For example, a mirror produces a virtual image.

A magnifying glass uses a converging (convex) lens. It produces a virtual image which appears larger than the actual object. The magnification can be calculated using the equation:

$$\text{magnification} = \frac{\text{image height (mm)}}{\text{object height (mm)}}$$

An imaginary horizontal line through the middle of the lines is called the **axis** and this is where the **principal focus** forms. In a **convex lens**, the light rays enter the lens **parallel** to one another and then **converge** at the principal focus **after** the lens. In a **concave lens**, the light rays enter the lens **parallel** to one another and then **diverge**. The principal focus is the virtual source of the diverging rays **before** the lens.





$$\text{power (D)} = \frac{1}{\text{focal length (m)}}$$

- D stands for dioptres which is the unit of measurement for lens power.
- In a **converging** lens the power is a **positive** value.
- In a **diverging** lens the power is a **negative** value.

Focal length depends on two factors: the **refractive index** of a material and how **curved** the surfaces of the lenses are. A higher refractive index makes the lens **flatter** in shape. To make a powerful lens thinner, a material with a higher refractive index can be used.

Objects which are a distance **greater than one focal length** away from a converging lens will produce a **real image**. Objects which are closer **than one focal length** from the converging lens will produce a **virtual image**.

The **lens equation** can be used to show the relationship between focal length, position of the **object** and position of the **image**:

$$\frac{1}{\text{focal length}} = \frac{1}{\text{distance between lens and object}} + \frac{1}{\text{distance between lens and image}}$$

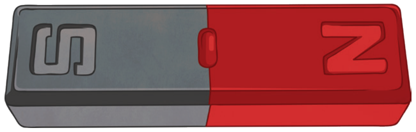
This equation can also be written as:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

AQA GCSE Physics (Separate Science) Unit 7: Magnetism and Electromagnetism

Poles of a Magnet

A magnet has two ends called **poles**: the **north pole** and the **south pole**. The magnetic forces of the magnet are strongest at the poles.



When two magnets are brought close together, they will **attract** or **repel**, depending on which poles are brought together:

- **Like poles** will **repel** one another e.g. N-N or S-S.
- **Opposite poles** will **attract** e.g. N-S.

The forces exerted between the poles of two magnets are a type of **non-contact force**: the magnets do not have to be touching for the effect to be observed.

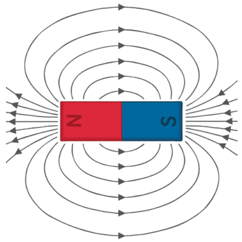
Remember that only **iron**, **cobalt** and **nickel** (or alloys containing these metals) are magnetic.

A **permanent magnet** is one with its own magnetic field. The magnetism cannot be turned on or off e.g. a bar magnet or a horseshoe magnet.

An **induced magnet** is a material which becomes magnetic only when placed within a magnetic field. Induced magnets only attract other materials and lose most (if not all) of their magnetism when removed from the magnetic field e.g. iron filings.

Magnetic Fields

The **magnetic field** is the area surrounding a magnet where the force is acting on another magnet or magnetic material. It can be observed using a compass placed at different points around a bar magnet. The field lines can be drawn by using the compass to mark the direction at a range of points.



A magnet always causes a magnetic material to be **attracted**. The strength of the magnetic field is determined by the proximity to the magnet.

When looking at a diagram of magnetic field lines, the force is strongest where the lines are closest together. The magnetic field of the magnet is strongest at the poles. The direction of the magnetic field shows the direction the force would act on another north pole.
As a result, magnetic field lines always come away from the north pole (like poles repel) and towards the south pole (unlike poles attract).

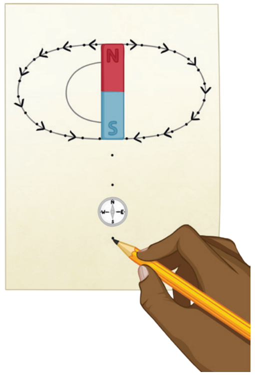
The earth produces a magnetic field and a magnetic compass uses this to help aid navigation. The core of the earth is made of iron (a magnetic material). A compass contains a small bar magnet shaped as a needle, which points in the direction of the earth's magnetic field.

Plotting Magnetic Field Lines

A magnetic compass can be used to plot and draw the magnetic field lines around a magnet.

You should be able to describe this method for a bar magnet.

1. Place the bar magnet in the centre of a sheet of plain paper.
2. Using a magnetic compass, position it on the paper somewhere around the magnet.
3. Observe the direction of the needle and carefully draw a dot at the circumference of the magnet, in line with each end of the needle. Make sure you include an arrow to indicate the direction of north.
4. Repeat steps 2 and 3 for several positions around the magnet.
5. Join the arrows to complete the magnetic field lines and whole pattern.



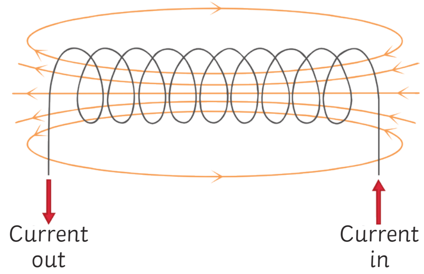
Electromagnetism

A circular **magnetic field** is produced when a current is passed through a conducting wire. This produces an **induced magnet**.

Switching off the current causes the magnetism to be lost.

The strength of the magnetic field can be increased by increasing the current flowing through the wire. The strength of the magnetic field is stronger closer to the wire.

Coiling the wire to form a **solenoid** will also increase the strength of the magnetic field. The strength of the magnetic field created by a solenoid is strong and uniform throughout.

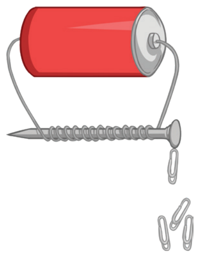


To increase the strength of the magnetic field around a solenoid you can...

- add an iron core;
- increase the number of coils in the wire;
- increase the current passing through the wire.

An **electromagnet** is a solenoid with an iron core. Electromagnets are **induced magnets** and can be turned on and off.

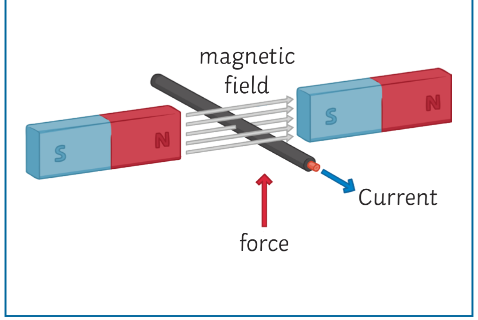
Electric motors, loudspeakers, electric bells and remotely controlled door locks all use **electromagnets**.



AQA GCSE Physics (Separate Science) Unit 7: Magnetism and Electromagnetism

The Motor Effect and Flemings Left-Hand Rule

When a wire carrying a current is exposed to the magnetic field of another magnet, then a **force** is produced on the wire at a **right angle** to the direction of the magnetic field produced.



This is called the **motor effect**.

The force produced by the motor effect can be calculated using this equation:

force (N) = magnetic flux density (T) × current (A) × length (m)

For example:
A current of 8A is flowing through a wire that is 75cm long. The magnetic field acting at a right angle on the wire is 0.5T. Calculate the force.

F = B × I × l

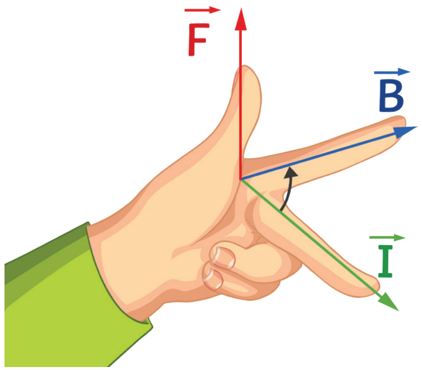
Remember: the equation uses length measured in m. The question gives you the length in cm so you need to convert it before you calculate your answer.

F = 0.5 × 8 × 0.75

F = 3N

From the equation we can see that the force acting on a given length of wire (e.g. 1m) will be increased if the current increases or the magnetic flux density increases. If the current flowing through a wire is **parallel** to the magnetic field, then **no force** is produced – there is no motor effect.

You might be shown a diagram and asked to indicate the direction of the force produced. **Fleming's left-hand rule** can help you do this because it represents the **relative orientation** of the force produced by the motor effect.

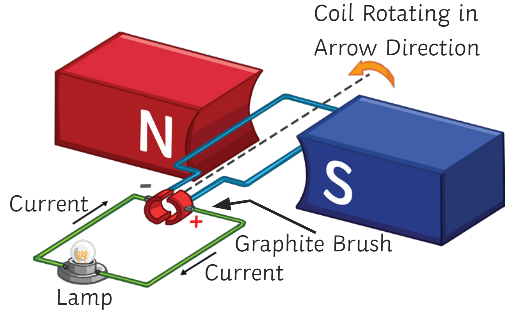


Remember:

- Use your **left hand**!
- The angle between your index finger and middle finger should be a **right angle** on the horizontal plane.
- The angle between your index finger and thumb should be a **right angle** on the vertical plane.
- Your **thumb** represents the direction of the **force**.
- Your **index finger** represents the direction of the **magnetic field**.
- Your **middle finger** represents the direction of the **current** flowing through the wire.

Electric Motors

When the wire carrying the current is **coiled**, the motor effect acting on it causes the wire to **rotate**. This is how an **electric motor** works.



As the **current** flows (from negative to positive), the force produced in each side of the coil acts in **opposite directions**, causing the coil to **rotate** overall.

When the coil reaches a **vertical position**, the force produced is now **parallel** to the magnetic field line and so would be **zero**. This would cause the motor to stop rotating.

To maintain the rotation of the coiled wire, a **split ring commutator** is used to supply the current to the wire. The DC supply reaches the split ring via graphite or metal **brushes** which maintain the connection while allowing it to rotate freely on the **axle**.

The two halves of the split ring commutator ensure that the **current supplied** to the wire **changes direction** each half-turn (or that the current supplied is the same direction on each side of the motor) and as a result, the force produced maintains a **constant rotation** in one direction overall.

AQA GCSE Physics (Separate Science) Unit 7: Magnetism and Electromagnetism

Headphones and Loudspeakers

Headphones work because they contain small loudspeakers inside them. A loudspeaker makes use of the motor effect to produce sound. Variations in the AC electric current supplied to the device causes variations in the magnetic field produced. These variations cause the cone in the loudspeaker to move and the vibrations are transferred to the air particles and generate a sound wave.

- An alternating current is supplied through a coil of wire in the loudspeaker.
- This produces an electromagnetic field around the wire.
- The electromagnetic field interacts with the magnetic field of the surrounding permanent magnetic and a force is produced (the motor effect).
- The force produced pushes the cone in the loudspeakers outwards.
- The current is reversed and the force changes direction, pulling the cone back inwards.
- The vibrations of the cone moving in and out creates vibrations in the air particles, which are transferred as sound waves.
- The sound waves produced match the electrical signals supplied.

Induced Potential and the Generator Effect

Induced potential or **electromagnetic induction** is when a **potential difference** (voltage) is created across a **conductor** (e.g. a wire) due to a change in the **magnetic field**.

If the conductor is connected in a **closed circuit**, then it will cause a **current** to flow.

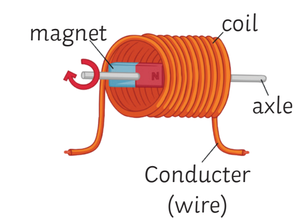
Induced potential can be produced by either...

- moving a **magnet** in a **coil** of wire;
- moving an **electrical conductor** (wire) through **magnetic field lines**;
- moving a **coil** of wire in and out of a **magnetic field**.

Moving the conductor in the **opposite direction** or reversing the **polarity** of the magnet will cause the potential difference to reverse and the current will flow in the opposite direction.

Continuously moving the magnet or conductor to repeatedly change the direction of the potential difference is how an **alternating current** is produced.

A **generator** uses an induced potential to produce an alternating current.



A magnet on an axle is positioned in a coil of wire. The poles of the magnet are on the outer edges as the magnet is spun on the axle. Every half-turn on the axle rotation, the poles are reversed (swap sides in the coil) and this causes the induced potential to change direction. This produces an alternating current in the conducting wire.

To increase the voltage of a induced potential you can...

1. increase the **strength of the magnet** used;
2. increase the **number of turns** in the conducting coil of wire;
3. increase the **area** of the coil;
4. increase the **speed of the movement** (of the magnet or conductor).

Turning the magnet more quickly will not only increase the **voltage**, but also increase the **frequency**.

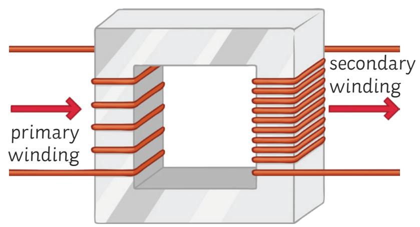
Transformers

A **transformer** changes the **voltage** using an **induced potential** (electromagnetic induction).

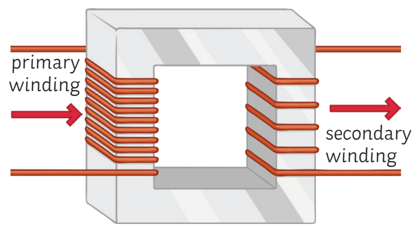
Transformers only work for an **alternating current potential difference**. A transformer is simply **two coils of wire** (primary coil and secondary coil) connected by an **iron core**.

There are two main types:

Step-up transformers: increase (step-up) the **voltage**. There are fewer primary coils than there are secondary coils.



Step-down transformers: decrease (step-down) the **voltage**. There are more primary coils than there are secondary coils.



Transformers (continued)

A current doesn't flow through the **iron core**. The role of the iron core is to **transfer the changing magnetic field** between the two coils only.

When an **alternating current** is supplied to the primary coil, it produces a magnetic field with the iron core. The magnetic field in the iron core constantly changes direction due to the alternating current.

The voltage of the induced potential in the secondary coil depends on the ratio of turns between the primary and secondary coils:

- If there are **more turns** in the **secondary coil**, the **potential difference** will be **greater** (a step-up transformer).
- If there are **fewer turn**s in the **secondary coil**, the **potential difference** will be **less** (a step-down transformer).

Remember: an **induced potential** can only be produced by a **changing magnetic fiel**d so it only works with an **alternating current (AC)** and **not a direct current (DC)**.

The power supplied by a transformer can be calculated using the equations:

power (W) = potential difference (V) × current (A)

Transformers are almost 100% efficient:

electrical power in = electrical power out

So…

potential difference across primary coil × current in the primary coil = potential difference across secondary coil × current in the secondary coil

This can also be written simply as:

$V_p I_p = V_s I_s$

Worked example:

Shannon is using her hair straighteners on holiday in Europe. A travel adaptor transforms the 110V AC mains supply to 230V. The current in the hair straighteners is 6A. Assuming the transformer is 100% effiecient, calculate the current draw by the adaptor from the mains supply (in the primary coil). Give your answer to two decimal places.

$V_p I_p = V_s I_s$

$110 \times I_p = 230 \times 6$

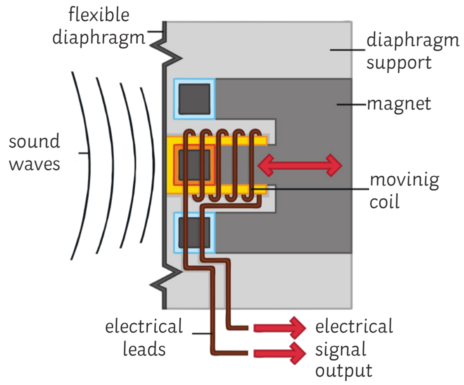
$110 \times I_p = 1380$

$I_p = \frac{1380}{110}$

$I_p = 12.55A$

Microphones

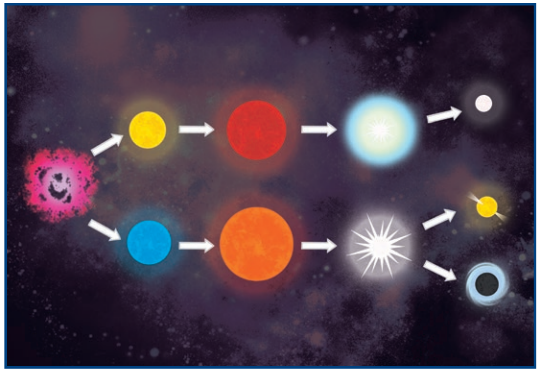
Essentially, a **microphone** works like a loudspeaker but uses the generator effect in reverse. Instead of using the alternating current to produce a changing magnetic field and cause movement in the cone, a microphone uses movement in a diaphragm to produce a changing magnetic field and create an alternating current.



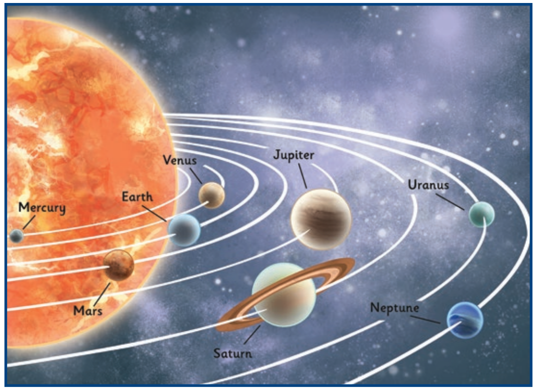
- The **sound wave** vibrations in the air particles are transferred to the **flexible diaphragm**.
- This causes the diaphragm to move, **vibrating the coil**.
- The coil moves through the **magnetic field** of the **permanent magnet** and an **induced potential** is created.
- The induced potential causes a **current** to flow in the **closed circuit** which the coil is attached to.
- The induced potential changes to match the vibrations of the sound waves, which results in the current changing to match the induced potential, transferring the sound wave.

AQA Physics Unit 8: Space Physics

Formation of a Star



The Solar System



The solar system is part of the Milky Way galaxy and is made up of the Sun and anything that goes round it (orbit). There are 8 planets and some dwarf planets, including Pluto.

Planets are objects that orbit a star (the Sun). A dwarf planet will orbit a star but will be too small to be a planet, or not quite fit the pattern of a normal planet. Pluto is an example of a dwarf planet. Moons orbit planets and are also known as natural satellites. Planets are natural satellites of the Sun. Artificial satellites are satellites that humans have built and they mostly orbit the Earth.

Formation of a Star

1. Stars are made from a cloud of dust and gas – a **nebula**. Gravity pulls the dust and gas together, forming a **protostar**.
2. The more dense the star, the hotter it becomes. Fusion of the hydrogen nuclei starts, emitting a lot of energy.
3. The next stage is the **main sequence star**. This stage will last for a few billion years. This is a stable phase as the force of gravity and fusion of hydrogen are balanced. Hydrogen is fused and forms helium; as this happens, energy is released.
4. Hydrogen begins to run out, turning the star into **a red giant (like the Sun)** or a **red super giant**, depending on the size of the star.
5. A red giant will become a **white dwarf** by getting rid of the outer layers of dust and gas. It will then cool down and become a **black dwarf**.
6. Red super giants will initially glow brightly. Then, they will explode into a **supernova**. The supernova will get rid of its outer layer of dust and gas and will form a black hole.

Orbits

Gravity is a force that causes planets and satellites to circle an object. It acts towards the centre of the orbit. This occurs in both natural and artificial satellites.

Higher Tier Only

When an object is in orbit around something, it is constantly changing velocity as the direction constantly changes.

The speed, however, will stay the same.

Examples of satellites include the planets orbiting the Sun and the Moon orbiting Earth.

Remaining in Orbit

For an orbit to remain stable, the radius must change if the speed changes.

The closer something is to an object, the quicker it has to travel in order to keep in orbit.

If the force is stronger, then the object will have to travel quicker to remain in orbit.

The Expanding Universe

Evidence suggests that the universe is expanding (getting bigger). Galaxies are moving further away from each other. The redshift provides us with some evidence for the expanding universe and the big bang theory.

When we see light coming from galaxies that are far away from us, the wavelength has increased. The light has shifted towards the red end of the spectrum (**redshift**) and is moving away from us. Galaxies that are more distant have a greater redshift which means they are moving away more quickly.

If you imagine dots on a balloon moving away from each other as the balloon is being blown up, this helps to visualise the expanding universe.

Dark Mass and Energy

There is so much about the universe that scientists do not fully understand.

Scientists have discovered dark mass and dark energy but they do not know much about it.

The Big Bang

The big bang is a theory about how the universe began.

In the beginning, matter in the universe took up a very small amount of space. This space was very dense and so became hot. This caused an explosion 13.7 billion years ago – the big bang. After **the big bang**, space then continued to expand as it is now.

Observations of supernovae since 1998 suggest that distant galaxies are moving away faster.

The big bang is a theory and is the best theory that we have at the moment.